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SQUIDVADERS!

Strange shrinking kraken take over the Pacific

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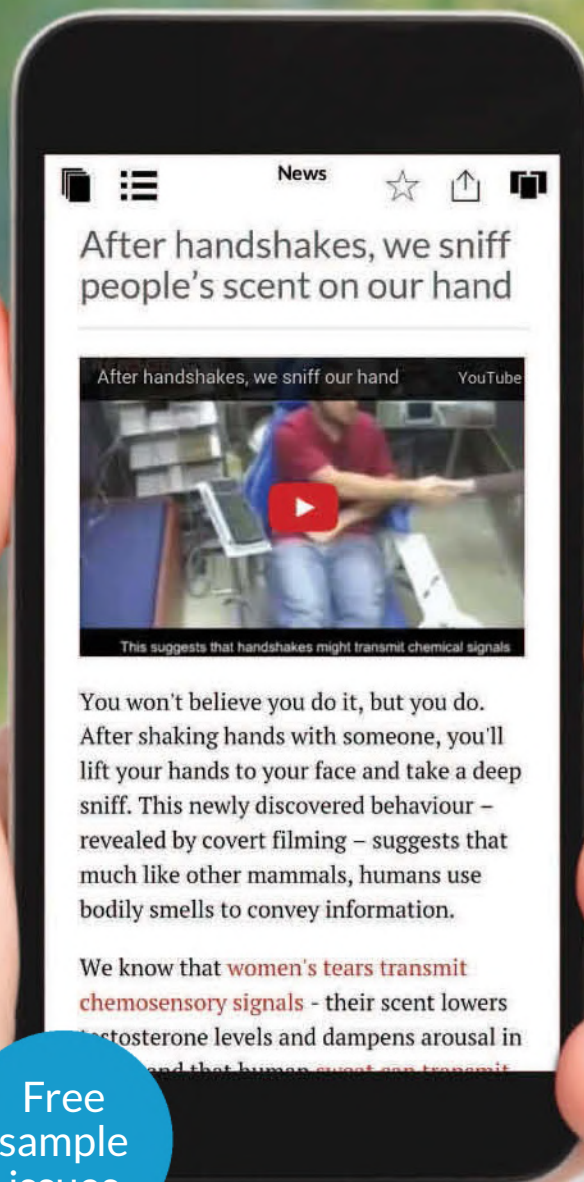
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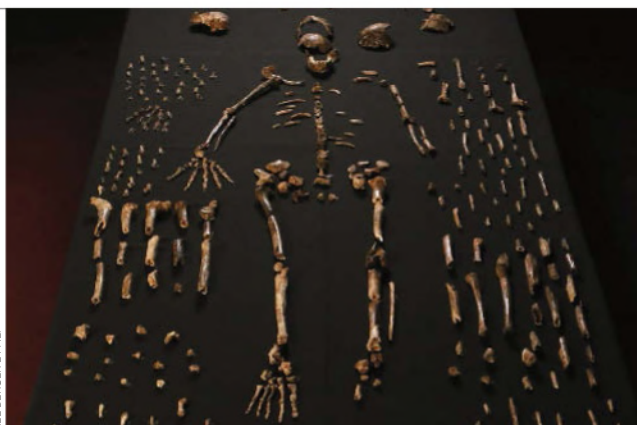
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LASZLO BALOGH/REUTERS

A crisis, not a drama

Discussion over refugees is dominated by fiction, not facts

THE shocking photos of Alan Kurdi, the 3-year-old Syrian refugee drowned and washed up on a Turkish beach, will go down in history as the moment that Europe's "migrant crisis" was recognised for what it is: a humanitarian tragedy. The sudden lurch in public and media sentiment – and subsequent backtracking by political leaders – was very welcome. But it also emphasised how the situation has been handled: by politicking and knee-jerk reaction rather than rational policymaking.

Human migration is a complex issue that touches the West's rawest nerves – immigration, radicalisation, inequality, economic security, national identity, and autonomy versus international cooperation. That makes it hard to deal with effectively. But efforts have also been complicated in many countries by anti-immigration parties spreading misinformation about those burning issues. When politics takes precedence over facts, tragedies tend to happen.

We can, and must, do better. The key word is "misinformation". Complex issues require nations to respond in an informed and sophisticated way, bringing all the available evidence to bear, acting on it – and explaining it to

reluctant electorates if needed. By these criteria, Europe has failed miserably (see page 10).

For example, the prevailing narrative has it that Europe is experiencing an unprecedented influx of both economic migrants and refugees. The numbers suggest otherwise: according to authoritative research, labour migration into Western Europe has been falling steadily since 2007. And while refugee numbers

"Large-scale human migration will be one of the defining issues of the 21st century"

have been climbing since the Arab Spring of 2010, they have still not reached 1992 levels, when millions of people fled the bloody disintegration of Yugoslavia.

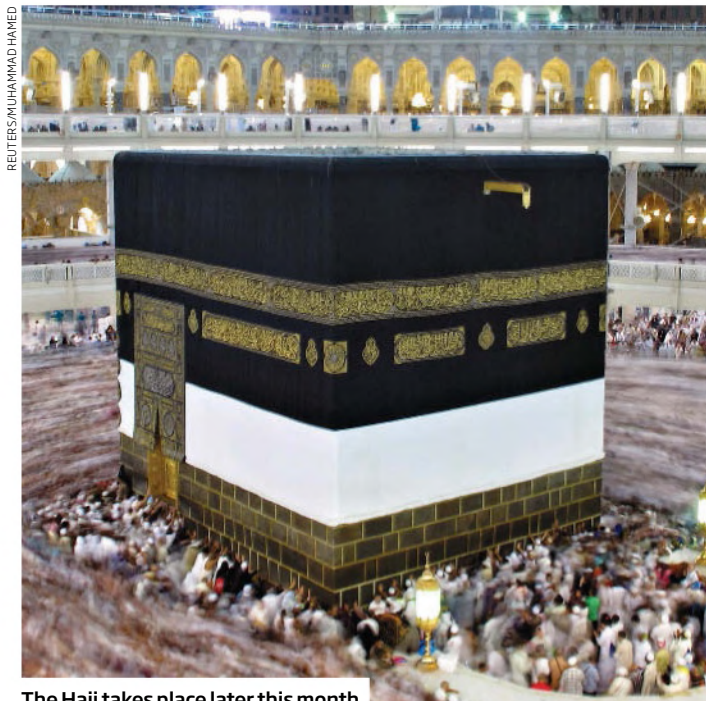
These are just the raw numbers. When it comes to more complex analyses, there are also surprises. For example, a study published last year found that, since 2000, immigrants in the UK paid more into government coffers than they took out in benefits. That was true both for migrants from Europe and elsewhere. They even managed this during a time of government deficits, when by definition the native majority was a net drain on public resources.

That research illuminates only one aspect of how immigrants affect societies, but it is not the only example of how knee-jerk assumptions about human migration often crumble under proper scrutiny.

Such counterintuitive facts and figures are well known in the smallish circle of social scientists who research them, but are barely visible in the wider debate. That urgently needs to change because, like it or not, the present crisis is just the start.

Those same experts agree that large-scale migration will be a defining issue of this century, driven by population growth, political instability and climate change, and enabled by increased global connectivity, both physical and digital. We cannot stop it by building fences or turning away boats. So we had better get a handle on it now.

This is not just an issue for Europe. Other countries, notably the Gulf states, Brazil, Australia, the US and Canada – the country little Alan's family was trying to get to – also have migration issues. We can all expect much more of the same in the future. If our leaders carry on making it up as they go along without recourse to evidence, they really will have a crisis on their hands. ■



The Hajj takes place later this month

Alzheimer's find

CAN Alzheimer's disease spread between people? Possibly, through a medical procedure banned in 1985 – but some say the evidence is too circumstantial.

John Collinge of University

"There is no definitive evidence that Alzheimer's can be transmitted between humans"

College London and his colleagues looked at the brains of eight people who had been injected with human growth hormone as children. The hormone had come from dead donors – but they had been harbouring Creutzfeldt-Jakob Disease (CJD). The eight recipients contracted CJD via the hormone and later died.

Now, fresh autopsies on their brains have revealed that six also had amyloid plaques similar to those seen in Alzheimer's – even though they had died between the ages of 36 and 51, long before the disease typically develops. Collinge believes molecules seeding the plaques were passed

to the recipients via the donated growth hormone, saying the donors must have been developing Alzheimer's as well as CJD (*Nature*, DOI: 10.1038/nature15369).

David Irwin of the University of Pennsylvania in Philadelphia – whose work suggests Alzheimer's can't be transmitted – is doubtful. Collinge couldn't analyse samples of the growth hormone to see if it contains the molecules.

"There remains no definitive evidence that clinical manifestations of Alzheimer's can be transmitted between humans," says Irwin.

You owe the planet

IF YOU live in the US or Australia, you owe more than US\$12,000. If you're in the UK, it's about \$4000.

These are climate debts, worked out by Damon Matthews at Concordia University in Montreal, Canada. He sees those who pollute more than their fair share – that is, above the global average – as being in "emissions debt".

Between 1990 and 2013, the US, for example, emitted an excess of 300 tonnes of carbon dioxide per person (*Nature Climate Change*, doi.org/7jb). That's about as much

Korea, where it infected 185 people, resulting in 36 deaths.

"The current outbreak is occurring close to the start of the Hajj, and many pilgrims will return to countries with weak surveillance and health systems," warned the World Health Organization last week.

Saudi Arabia itself is thought to be well prepared. "They have agents on the ground and clinics devoted specifically to MERS," says WHO spokesman Christian Lindmeier. "The authorities are on extremely high alert for the Hajj."

He says pilgrims should avoid close contact with people who have flu-like symptoms, report any symptoms immediately, and avoid contact with camels, the main reservoir for the virus identified so far.

as is produced by driving a family car from Los Angeles to New York and back 150 times.

The US Environmental Protection Agency estimates that each tonne of CO₂ produced today has a social cost of about \$40, so the debt per person is \$12,000.

"It is important to acknowledge and own up to how much we in the developed world have over-contributed to historical climate change," says Matthews. He hopes the work will inform any future talks over how much rich nations should pay poor ones to adapt to climate change.

New Stonehenge

MOVE over, Stonehenge, we have found "Superhenge". An even more massive stone monument has lain hidden for thousands of years just a short walk away from the famous prehistoric site.

The newly discovered remains are at a site called Durrington Walls, already well known to archaeologists. Here, a bank and inner ditch were built around a natural depression, creating a horseshoe-shaped structure



Supersized henge

about half a kilometre wide. It resembles an arena, and some think that is exactly what it was.

Now the mystery has deepened: remote sensing surveys have revealed that around 4500 years ago giant stones were arranged along the ground where the bank now is. Around 30 stones up to 4.5 metres long are buried there, and the surveys suggest there were at least 90 originally.

It appears the stones were deliberately toppled and buried when the bank was built around Durrington Walls, for reasons that are unclear. There are no plans as yet to excavate the stones.

Soggy rockets

HOUSTON, we'll have a problem. The effects of climate change could mean rocket launch sites will soon be underwater, NASA has warned.

The space agency has launch pads and research centres dotted along the US coast, and more than two-thirds of its infrastructure is at elevations that are within 5 metres of sea level. This is because launching near the ocean is much safer than over land.

But their proximity to the water has put many sites at risk of flooding due to rising seas. "Some are more at risk than others," said NASA climatologist Cynthia Rosenzweig in a recent NASA report. "But sea level rise is a very real challenge for all of the centres along the coast."

Models suggest that sea levels at the Kennedy Space Center in Florida, the launch site for the moon landings and countless space shuttle missions, will rise by as much as 20 centimetres by the 2050s – or triple that if ice sheets in Greenland and Antarctica continue to melt.

NASA plans to redesign or move vulnerable buildings and improve sea defences to hold back the rising tides. But eventually, some launch sites may have to be abandoned.

Bone-spotting club

ALWAYS dreamed of being a fossil hunter? Now's your chance – and you don't have to leave home.

A citizen science project called FossilFinder is asking volunteers to look through high-resolution photos of the Turkana basin in Kenya taken from drones and kites, with the hope that they will spot newly exposed fossils before they erode away.

Many early human fossils have been found in the region. The first photos, of a fossil hotspot to the east of Lake Turkana, cover only a tiny part of it.

The project was set up by the Turkana Basin Institute in Kenya and the University of Bradford, UK, to get a better understanding of the geology and the past environment by identifying where fossils are found and what kind of fossils are present.

There is, of course, a chance that you could be the first to spot the bones of one of our distant relatives – any promising-looking finds will be followed up on the ground.

Dinosaur fans will have to wait, however: there are currently no plans to post pictures of rocks dating back to the dinosaur era.

Moulting seals shed mercury too

SEAL fur may be toxic. Mercury is building up even in pristine areas, and it's coming from an unexpected source – moulting elephant seals.

Industrial pollution can release mercury into the environment, where it may end up as an organic compound called methylmercury. This is taken up by bacteria, and it builds up in organisms much higher up the food chain, including top predators such as elephant seals.

But it doesn't end there. "Elephant seals undergo a catastrophic moult," says Jennifer Cossaboon of San Diego State University in California. "It comes off in big sheets of fur and the top few layers of skin."

Cossaboon has traced mercury in California's coastal Año Nuevo State

Park to moulting seals. She calculates that each year seals in the US and Mexico release a similar amount of methylmercury as enters San Francisco bay. Around 40 per cent of California, the most populous US state, drains into the bay, including areas of heavy industry (PNAS, DOI: 10.1073/pnas.1506520112).

It isn't yet clear if methylmercury in the seal's coats can work its way back into the food chain, but if it can, then hair and feathers shed from other species may be releasing mercury into food webs, too.

"We're opening the methylmercury era," says Amina Schartup of Harvard University. "We're going to uncover more and more things that we didn't realise were out there."

FRANIS LANTING/MINT IMAGES/SPL



A big fat source of mercury

60 SECONDS

'Blue bastard' is real

The seafarers' tales were true. An elusive "kissing" fish so hard to catch that anglers in Australia call it "blue bastard" has been documented – and its nickname has stuck. Its Latin name is *Plectorhinchus caeruleonothus*: *Caeruleo* is blue, *nothus* is bastard. The kissing is caused by rival males locking jaws during a fight (Zootaxa, doi.org/7h9).

Fat lot of good

Believing your weight is determined by your genes is bad for your health. A study of 8000 people found that those who agreed most strongly that some people are just born fat and can't do much to change it were more likely to eat unhealthily and less likely to exercise. They were also more likely to be overweight and have high blood sugar (*Health Education and Behavior*, DOI: 10.1177/1090198115602266).

All aboard the Starliner

Aerospace firm Boeing has revealed the official name of its upcoming spacecraft, formerly known by the less evocative moniker CST-100. The Starliner capsule is designed to ferry astronauts and cargo to and from the International Space Station, and will begin test flights in 2017.

Name that storm

Brits love talking about the weather – now they can name it too. The Met Office is teaming up with its Irish equivalent, Met Éireann, to crowdsource names for storms that could have a medium or high impact. The US already names storms in a bid to raise awareness of their risks.

Mum knows best

Even astronauts have to call their parents sometimes. Andreas Mogensen, the first Dane in space, spoke to his mother via video link after arriving at the International Space Station last week. She urged him to call when he was back on Earth. "Yeah, yeah, I promise," he replied.

Deep cave yields a new human

The copious remains of *Homo naledi* shake up our view of our past

Colin Barras

ONE thousand four hundred bones, 140 teeth, belonging to at least 15 individual skeletons – and that's just what was recovered in a single short field session.

The early human fossil record isn't normally this rich. For a century, palaeoanthropologists have generally learned to make do with slim pickings – part of a face here, a jawbone fragment there. Now, from the depths of a cave in South Africa, has come a monster cache of hominin bones from a previously unknown early species of our own genus, *Homo*.

"It's unique," says Fred Spoor at University College London, who has seen casts of some of the finds.

The sheer number of bones and their location hint at something even more astonishing: the bodies they belonged to appear to have been left deliberately in the cave. This has never been seen before in such a primitive human, and could have big implications for understanding the origins of modern human behaviour (see "Did ancient hominins bury their dead?", opposite).

The first signs that something unusual was unfolding came in October 2013, when Lee Berger at the University of the Witwatersrand in Johannesburg, South Africa, advertised for people with good archaeological skills and a lack of claustrophobia to come forward. The successful applicants flew to South Africa a few weeks later to help remove hominin bones and teeth from the cramped Dinaledi chamber in a cave system a few tens of kilometres from Johannesburg (see diagram, opposite).

There are still thousands more remains in the cave, according to Berger. "Once we realised the full



It's an anatomical mosaic

potential, we decided the best thing to do was to lock down the site, and engage the entire community to make a decision on what to do there next," he says.

But what has been recovered so far tells an extraordinary tale. The species the bones belonged to had a unique mix of characteristics.

"It may not be that closely related to us, but could have had a cognitive ability essentially equal to ours"

Look at its pelvis or shoulders, says Berger, and you would think it was an apelike *Australopithecus*, which appeared in Africa about 4 million years ago and is thought to be an ancestor of *Homo*. But look at its foot and you could think it belonged to our species, which appeared just 200,000 years ago.

Its skull, though, makes clear that the brain was less than half the size of ours, and more like that of some species of *Homo* that

lived about 2 million years ago.

"It doesn't look a lot like us," says Berger. Even so, he and his colleagues think that, on balance, the features of the skull, hands and teeth mean the new species probably does belong in our genus. They have named it *Homo naledi* (*eLife*, DOI: 10.7554/eLife.09560).

Its anatomy suggests it is one of the earliest members of our genus to evolve, but frustratingly, we don't yet know exactly how old

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the skeletons are. They might turn out to be 2 or 3 million years old, dating back to the time when *Homo* first came on the scene.

But even if they prove to be much younger – 100,000 years old, say – that would be significant, says Berger. It would make them a human version of the coelacanth, he says: an ancient species that survived, unchanged, into essentially modern times. “Whatever the age, it’s exciting.”

The team refers to the fossils’ mixture of features as “anatomical mosaic”. We have previously seen such a mosaic in *Australopithecus sediba*, a 2-million-year-old hominin that Berger and his colleagues excavated in 2008 from the Malapa cave, a few kilometres away. “*Naledi* is almost the mirror of *sediba*,” says Berger. “Almost everywhere in the *sediba* skeleton where you see primitive features, in *naledi* you see derived features. And almost everywhere that *sediba* is derived, *naledi* is primitive.”

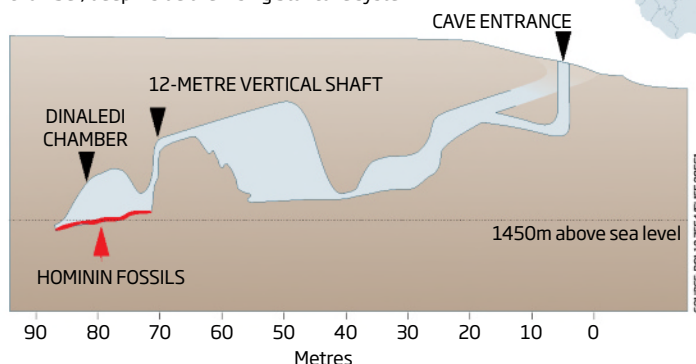
Although it was just about possible to dismiss *A. sediba*, with its assortment of ancient and modern features, as a quirk of human evolution, the new find hints that such “mosaicism” is not the exception in early humans but the rule, says Berger.

That has implications for how we interpret other early human fossil finds representing the transition from *Australopithecus* to *Homo*, he says. These fossils generally amount to just a few fragments rather than complete skeletons. “Both *sediba* and *naledi* say you can’t take a mandible [lower jaw], a maxilla [upper jaw] or a collection of teeth and try to predict what the rest of the body looks like,” he says.

But Spoor says *H. naledi* could really be a localised exception. “If you have lots of bones scattered all across East Africa, that might actually give you a better indication of what’s going on in terms of human evolution over a widespread region,” he says.

A fossil treasure trove

To reach the massive stash of bones now said to belong to *Homo naledi*, researchers had to navigate a vertical shaft leading to the Dinaledi chamber, deep inside the Rising Star cave system



Not that this viewpoint diminishes the importance of the find. “The contribution of these fossils is fantastic,” says Spoor. “I don’t think many people will have a problem with the interpretation: it’s a new species and I think it does belong in the genus *Homo*.”

Inevitably, though, there are dissenting views. “To me, having studied virtually the entire human fossil record, the

specimens lumped together as *Homo naledi* represent two cranial morphs,” says Jeffrey Schwartz at the University of Pittsburgh in Philadelphia.

Ian Tattersall at the American Museum of Natural History in New York shares that view. Last month, he and Schwartz wrote an article calling for researchers to think carefully about classifying new fossils as belonging to *Homo*.

As for the Dinaledi finds,

Schwartz and Tattersall point out that although the foreheads of some of the new skulls are gently sloped, one skull has a taller forehead with a distinct brow ridge – suggesting two species are present. “Putting these fossils in the genus *Homo* adds to the lack of clarity in trying to sort out human evolution,” says Schwartz. Berger disagrees, saying this can be explained by differences between males and females of the same species.

Either way, all can agree that the new find is a remarkable addition to the human fossil record. “This is an amazing assemblage of fossils that should keep paleoanthropology buzzing for a long time,” says Tattersall.

Dean Falk at Florida State University in Tallahassee is especially excited by the fact that Berger’s team has produced a cast of *Homo naledi*’s small brain. Images of it hint at interesting features close to one brain region associated with speech in modern humans, she says.

Berger says it’s possible that for the first time, we have found another creature not that closely related to us, yet with a cognitive ability “different but essentially equal to ours”.

The find is also a reminder that the fossil record still has rich treasures to offer, he says. “This stuff is still out there, and it’s out there in abundance.” ■

DID ANCIENT HOMININS BURY THEIR DEAD?

The discovery of more than 1500 fossilised human bones and teeth in one place is unusual (see main story), but what’s missing from the site is also extraordinary. Besides a few rodent fossils and the remains of an owl that probably fell into the Dinaledi chamber by mistake, there are no other vertebrate species present. How so?

Lee Berger at the University of the Witwatersrand in Johannesburg, South Africa, and his colleagues looked at various explanations. Carnivores could have brought the human remains to the chamber, but there are no gnaw marks, and it’s rare for just one species to be targeted.

The ancient humans could have fallen in by accident – but few would wander deep enough into the caves to stumble upon the chamber’s entrance. What’s more, the remains include those of infants, making

this idea even more implausible.

Only one scenario works, they say: *Homo naledi* deliberately disposed of its dead in the chamber. Perhaps the bodies were gently dropped down the shaft (see diagram, above) which researchers squeezed through to recover the bones (eLife, DOI: 10.7554/eLife.09561).

There are precedents for this. At Sima de los Huesos in the Atapuerca mountains of Spain, for example, 28 hominin skeletons were recovered from a deep pit. But these hominins were big-brained – they looked and behaved rather like us. *H. naledi* had a brain less than half the size of ours.

“It’s fair to say that *naledi* individuals recognised their own mortality and the other self that comes with death,” says Berger. The find is likely to “squash the sacred cow” that this sort of behaviour requires a big brain, he says.

Refugees welcome: the numbers add up

Europe's leaders are under pressure to accept more refugees. It's not just the right thing to do, it makes economic sense

Debora MacKenzie

A PICTURE really is worth a thousand words. For more than a year, world news has reported desperate refugees, most from war-torn Syria, dying in their attempts to reach Europe. Most governments refused to let them in.

That changed last week with the photo of 3-year-old Alan Kurdi, dead on a beach in Turkey after a boat taking his family to Greece capsized. Now Europeans are demanding more help for asylum seekers. EU governments had agreed to resettle only 32,000 across Europe; on Monday 14 September they will debate upping that to 160,000.

Already this year 362,000 illegal migrants have arrived in Europe and thousands continue to pour in, says the International Organisation for Migration. An estimated 80 per cent are refugees from violence; Europe is legally obliged to give them asylum.

Yet Europe – and the rest of the world – are giving precious little. Researchers who study human migration say countries offer two reasons: fear that letting in some refugees will encourage more, and that migrants will be an economic burden. Yet the evidence shows both beliefs are false.

The EU's asylum laws were designed in the 1990s to handle small numbers of people. They

don't necessarily require people to stay in the first country they arrive at – where the fingerprints of refugees are held in the EU's Eurodac database, says Madeline Garlick of the Migration Policy Institute Europe. But countries apply that rule, she says, because it is an administratively easy way to grant refugee status.

That means thousands of people have accumulated in squalid camps in Greece, Italy and Hungary. A 2001 directive empowers the EU to bypass this system and admit asylum seekers rapidly in cases of "mass influx". In July, EU member states used it to agree a voluntary plan to relocate 32,000 people stranded in Italy and Greece, roughly according to the receiving country's size, GDP, unemployment rate, and how many refugees it has already.

Apart from that, the EU has never used its emergency plan, says Garlick, because "member states fear this will be a pull factor for other people from the same country". Observers say this is why the UK refuses migrants who have already entered Europe – it would encourage more to come. "No existing sound research substantiates the political claim that giving people asylum in Europe stimulates more flow," says Alexander Betts, head of the Refugee Studies Centre at the University of Oxford. "Nearly all refugees want to go home. They don't sit in refugee camps calculating where they can get the best benefits."

"There is no evidence of a pull

across the Serbian-Hungarian border. Others post real-time updates about what areas are safe to travel through – where water is safe to drink, for example.

Last week, when one group boarded a train that appeared to be bound for the Austrian border but then stopped in the town of Bicske, those with phones posted warnings to those still waiting in Budapest.

"It's imperative that the people in the midst of it have access to communication so they can tell their story of what's happening," says Kate Coyer, director of the Civil Society and Technology Project at Central European University in Budapest.

Meanwhile, social networks like WhatsApp also provide a critical link to family members left behind.

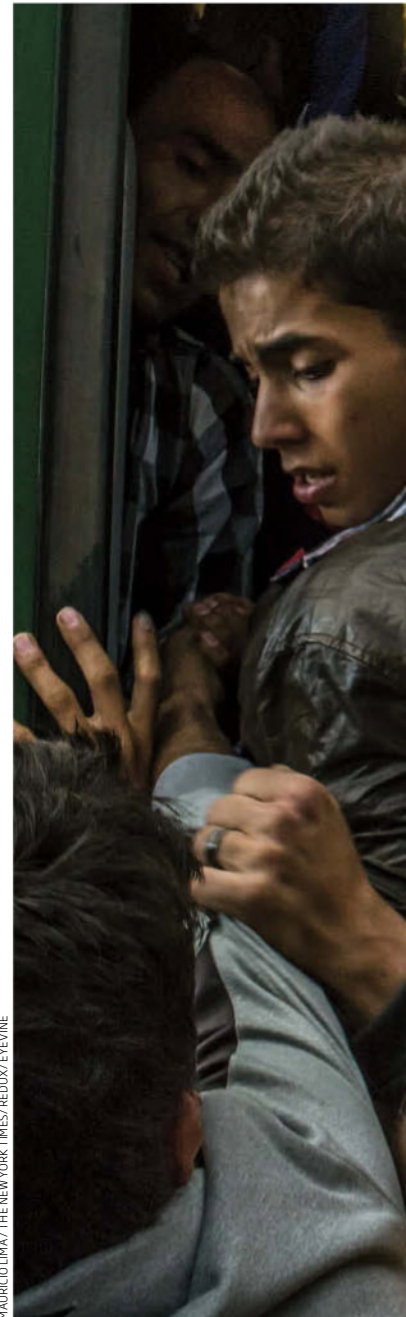
Aviva Rutkin

SMARTPHONE LIFELINE

Smartphones have become the new vital survival tool for many who have left Syria. Some say they relied on their phone's GPS to navigate the thousands of kilometres into Europe.

For example, The International Rescue Committee (IRC) documented one man's trip from Aleppo in Syria to Hamburg, Germany, as he travelled by ferry, train, taxi, and foot. Throughout the two-month journey, he said, GPS helped guide the way.

In addition, Facebook groups offer critical advice for those thinking of fleeing or already on the road. Some groups help connect traffickers with their clientele. Those travelling on their own can look up how-to guides written by others who've made it. One refugee showed a reporter at Public Radio International a video explaining, step-by-step, how to get



MAURICIO LIMA / THE NEW YORK TIMES / REDUX / EYEVINE

factor," agrees Ian Goldin, head of the Oxford Martin School on global challenges. "If you halved the risk of death, would that make more come? Desperate people don't make that calculation."

"Nearly all refugees want to go home. They don't sit in camps calculating where the best benefits are"



Help is at hand

Any pull is insignificant compared to push – such as the ever-increasing hardship in Middle-Eastern refugee camps, Goldin says.

One EU country seems unfazed: Germany says it can take 800,000 asylum seekers this year. It counts on immigrants to replenish its ageing workforce and the EU's emergency asylum rules say

resettled refugees can legally work. Germany had 200,000 more deaths than births in 2012, more than compensated by 391,000 immigrants. In contrast, UK prime minister David Cameron bowed to public pressure and this week said the country would take just 20,000 Syrian refugees by 2020.

Even without a worker

shortage, migrants needn't be a burden. On 4 September the World Bank, the UN's International Labour Organization and the OECD club of rich countries issued a report concluding that "in most countries migrants pay more in taxes and social contributions than they receive."

In a study last year, researchers at University College London

CITIZEN SUPPORT

For the Syrian refugees at Budapest station, charging a phone can be tricky. There's one outlet in the train station, another in the nearby migration aid offices, a few power lines offered up by satellite news trucks on the scene. Local businesses are a gamble – some have started charging high prices for the privilege of plugging a phone in.

So since last week, Kate Coyer of the Civil Society and Technology Project at Central European University in Budapest and her colleagues have been plugging power strips into the area's few available public outlets, so more people can use them.

For internet, the group turns volunteers into walking Wi-Fi beacons. For about \$100, you can pick up ready to use Wi-Fi hotspot and prepaid SIM cards, pop it all into someone's backpack, and send them out into the crowd. The networks last for about 6 hours on one charge, and can support around a dozen users at a time.

Online, other concerned citizens have found ways to help. The blog Refugees Welcome Pad compiles useful information including health brochures, asylum laws and missing persons reports. It's now enlisting helpers online to translate documents into Arabic and Farsi.

Another site, also named Refugees Welcome, bills itself as "Airbnb for refugees". There, German citizens willing to share their homes or sponsor a month's worth of rent can connect with people who need somewhere to stay.

The creators of the site are now working with volunteers from around the world, including the UK, to set up similar services in their home countries. Iceland residents launched their own initiative to offer homes or services last week: a Facebook group named "Syria is calling".

One man, who fled Syria for Turkey, even launched an app for fellow refugees. Gherbetna offers step-by-step help with government forms and maintains a list of job ads and friendly businesses. On a forum, the newly arrived can post more specific requests for help. Aviva Rutkin

THE TOLL OF TRAVELLING

The refugees' arduous journeys to Europe follow years of upheaval and compromised healthcare. So Europe's health services will be treating a complex combination of physical and psychological problems as the new arrivals settle in.

Diarrhoea, gastrointestinal problems and respiratory infections can be common, and children who have been unable to get all their vaccinations may be vulnerable to diseases like measles.

But refugees also suffer a range of chronic, non-communicable conditions. A UN High Commissioner for Refugees (UNHCR) study from 2013 found that Syrians arriving at camps outside their country's borders had high rates of diabetes and high blood pressure.

On top of all this, people who've had to squat in cramped conditions during their journey may find it difficult to walk once they reach their destination.

"They also suffer skin problems such as sunburn and exposure to salt if they've travelled by sea," says Sharuna Verghis, co-founder and director of the Health Equity Initiative, a charity based in Kuala Lumpur, Malaysia.

Of those arriving in Europe from war zones, many have already endured years of physical and mental trauma. "This means they're already carrying a considerable burden in terms of mental health issues," says Verghis.

This can include panic attacks and mood disorders, she says, and can be exacerbated by uncertainties over a person's legal status once they reach a safer country. The UNHCR study found that 21.6 per cent of Syrians in a refugee camp in Jordan had generalised anxiety disorders, while 8.5 per cent had post-traumatic stress disorder.

MENTAL TRAUMA

Health workers are advised to take into account the mental health of the refugees they treat. People who have experienced serious, persistent worries about their safety may be suffering from nightmares and flashbacks, and may find it hard to trust those trying to help them.

Safe, supportive environments will be needed to provide the best possible care. Women who have suffered sexual violence may be reluctant to tell doctors about their experiences and medical needs for fear of stigmatisation.

Verghis says identifying exceptionally vulnerable people, including those who are disabled or have been tortured, should be a priority. But first, she says, basic facilities must be provided for refugees while their needs are being assessed in their new countries - toilets and food, as well as sanitary towels for women, and diapers for babies.

Andy Coghlan

found both European and non-European immigrants to the UK more than pay their way. Non-Europeans living in the UK since 1995 brought £35 billion worth of education with them. Those who arrived between 2000 and 2011 were less likely than native Brits to be on state benefits, and no more likely to live in social housing. Unlike natives, they contributed a net £5 billion in taxes during that period.

That is partly because most migrants are young and need relatively little in the way of benefits. Their economic impact approaches that of natives as they age and assimilate. But the positive effect can be substantial: Carlos Vargas-Silva of the Migration Observatory at the University of Oxford reported this year that letting in 260,000 immigrants a year could halve the UK's public debt 50 years from now. "There are more than a dozen good studies now that point to a net positive effect of migrants on the economy," says Goldin.

"A dozen good studies now point to a net positive effect of migrants on the economy"

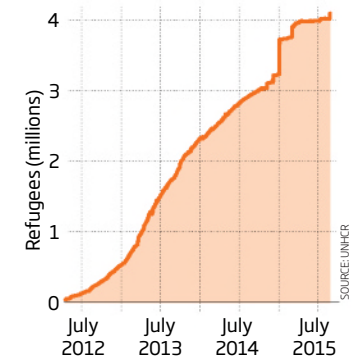
"Most data shows the economic impact is generally positive," agrees Betts, especially when immigrants are well educated, as most Syrians are. "Unlike ordinary migrants, refugees didn't choose to come," says Betts, potentially making their impact slightly different. But that means they will go home if they can, or if not, adapt like other migrants.

"There can be local negative effects on jobs, but that can be managed," says Betts. For example minimum wages can stop immigrants undercutting locals.

Some studies show migrants create jobs for locals, says Mathias Czaika of the International Migration Institute at the University of Oxford. "An influx of

Fleeing for their lives

The number of registered Syrian refugees has risen rapidly since the country's civil war escalated in mid-2012



migrants can depress wages, but mostly for other migrants, and only 1 to 3 per cent. Mostly the impact on wages or jobs is neutral or positive."

Germany has no doubts. "Every euro we spend on training migrants is a euro to avoid a shortage of skilled labour," German state governments declared last week. Otherwise, they say, they would have to spend more on benefits, as the labour shortage hurts industry and jobs.

So why do doors stay shut elsewhere? The reasons, say the researchers, are not economic, but fear of the cultural impact of foreigners. In August, for example, Slovakia said it would take only Christian Syrians.

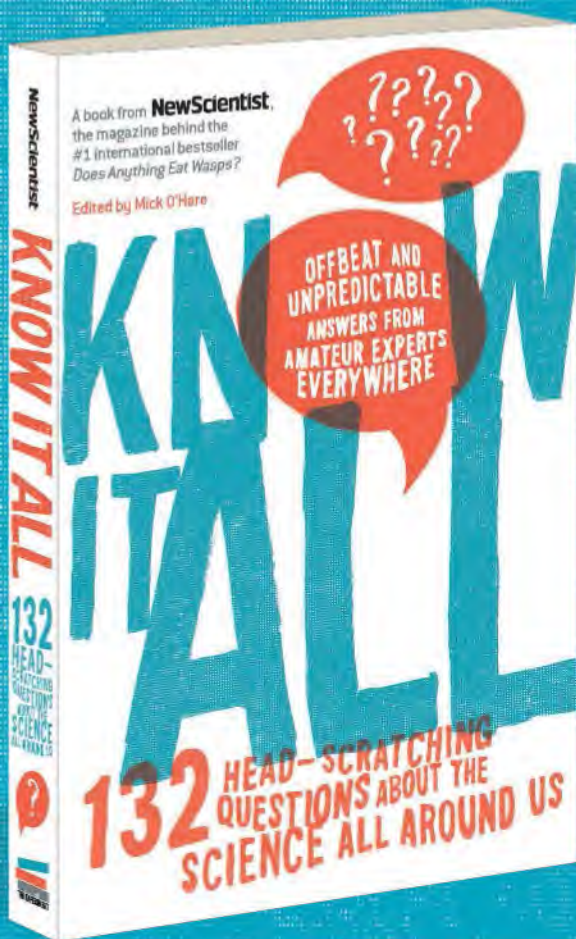
But Europe will have to learn how to deal with cultural differences, and get its asylum rules in order, because more refugees are coming. The situation for Syrian refugees in Jordan, Turkey and Lebanon is worsening, so more may be forced to look elsewhere, says Betts. "They and other countries with large numbers of refugees, like Kenya, need more help, or the entire refugee regime will collapse."

Climate triggered the crisis in Syria, so the world must brace itself for more climate refugees in the years to come. ■



Treat body and mind

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Catch cancer as it spreads with a trap

Clare Wilson

THE trouble with cancer is it spreads – sometimes even before someone knows they are ill. A small implant that traps cancer cells as they migrate through the blood could make a lifesaving early-detection system.

“This could be the canary in the coal mine,” says Lonnie Shea of the University of Michigan at Ann Arbor, one of the developers.

So far the idea has been tested in mice. If it translates to people, then the implant could be scanned for cancer cells while still inside the body – either by doctors, or one day perhaps just with a smartphone. “That’s the fantasy,” says Shea.

Shea devised the approach along with Jacqueline Jeruss, a breast cancer surgeon. Jeruss had noticed how common it was for her patients’ first symptom to be breathlessness – as the cancer had already spread to their lungs.

They and their colleagues devised an implant made from an inert porous material already used in medical devices, and loaded it with a signalling molecule called

CCL22. This attracts certain immune cells, which encourages cancer cells to follow suit.

They implanted the device under the skin of mice with a version of breast cancer, and found tumour cells in it after two weeks (*Nature Communications*, doi.org/7js).

In experiments on other mice, the team showed that cancer cells

could be detected in the implant while it was still in place, via a new scanning system called optical coherence tomography (OCT).

This technique, which can penetrate living tissue by a few millimetres, involves measuring the way light is scattered off large molecules and structures inside cells. Cancer cells can be detected because they are denser internally. Various firms are developing devices that would let OCT be done with a smartphone.

In mice, the implants cut the number of tumour cells that migrated to secondary sites like the lungs. They probably wouldn’t

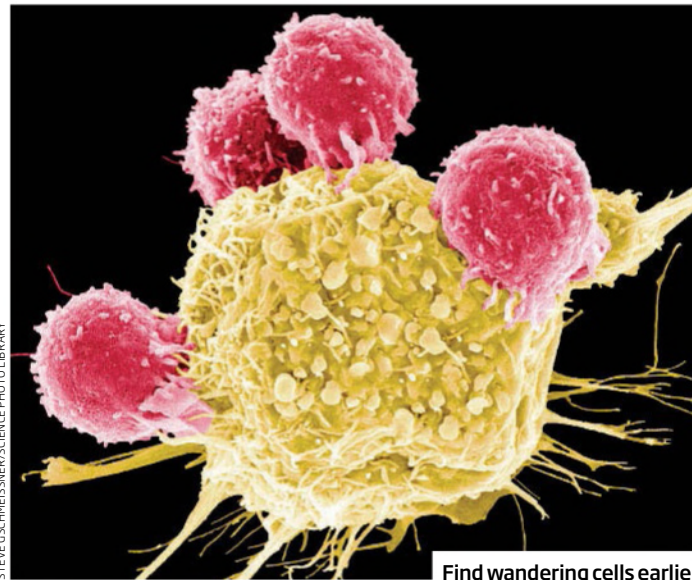
trap enough cells to work as an anticancer therapy, says Shea, but the implant could boost people’s chances of survival by identifying early on that cancer cells are on the move – allowing the patient to begin chemotherapy right away.

The main challenge, says Shea, will be getting the OCT scanner to penetrate human skin, which is thicker than rodent skin.

Other groups are investigating tumour traps that attract certain types of cancer cells via different, more specific, chemical signals. The new implant should in theory attract a wide range of cancer cells – although so far the team have only shown it works for one tumour type other than breast cancer, in unpublished work.

They envisage first using the trap in women at a high risk of breast cancer, such as those who have already had surgery to remove a tumour and might experience a recurrence. If a scan reveals that cancer cells are present, the implant could even be removed and the cells analysed to see which drugs they are most susceptible to.

Gerhardt Attard of the Institute of Cancer Research in London says there is growing interest in personalising treatments by testing cancer cells in the blood. “This could be a very powerful way of risk stratifying patients for treatment,” he says. ■



Find wandering cells earlier

Spider galaxies guzzle gas from the cosmic web

LIKE cosmic spiders, dwarf galaxies have been caught feasting on blobs of gas spread across a hidden web.

The idea that galaxies grew fat by eating from the cosmic web – a giant mesh of dark matter beaded with clouds of cold gas – has been around for a while. Simulations suggest that as the gas clouds fall into the gravitational clutches of a galaxy, they spark bursts of star formation.

But the process has been hard to observe in practice. Most galaxies near us, and our own Milky Way, are filled with hot gas that warms approaching material, preventing it from collapsing into stars. And because clumps of cold gas in intergalactic space do not emit much light, they are hard to spot.

The clincher would be to watch a blob of fresh gas triggering a burst of star formation in a small galaxy that is not building many stars on its own.

Now a team led by Jorge Sánchez Almeida of the Astrophysics Institute of the Canary Islands in Spain has done just that. “It’s as close to a

smoking gun as I’ve seen so far,” says astronomer Chris Churchill of New Mexico State University in Las Cruces.

To find the fresh gas, Almeida’s group looked at a set of small, faint galaxies with a low proportion of elements that are heavier than hydrogen and helium. They were able to infer how oxygen levels varied across these galaxies’ discs.

They found that the star-forming regions had about one-tenth as much

oxygen as elsewhere in these galaxies. This was a sign of newly arrived gas powering star formation, they concluded: it had to be recently added because any old gas would lose its distinctive chemical signature within a few hundred million years as it mingled with other gases.

Blobs of gas moving along the cosmic web could explain the very existence of these galaxies, says Almeida. They might be normal dwarf galaxies that have been spurred to make new stars by fresh gas, the recent arrival of which diluted their heavy element content (*Astrophysical Journal*, doi.org/7hp). Joshua Sokol ■

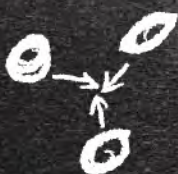
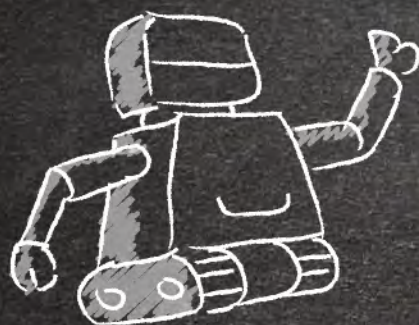
“The idea that galaxies grew fat by eating from the cosmic web has been hard to observe in practice”

A career in science, it's not always what you think

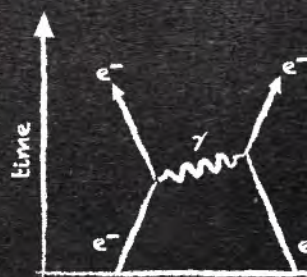
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$$DR_{ADC} = 20 \times 10^4$$
$$= (6.02 \times 10^{23})$$





Hawk's invisible force field protects hummingbird nests

WHEN you're tiny, it's good to have big friends in high places. Living in the shadow of hawks means hummingbirds can protect their eggs and chicks from being eaten by voracious jays.

"The jays are food for the hawks, and the hummingbird eggs are just too small and take too long for a predator like a hawk to find," says Harold Greeney at the Yanayacu Biological Station in Cosanga, Ecuador.

Greeney's team studied the birds in the Chiricahua mountains of Arizona over three years and found that jays avoided raiding hummingbird nests found in each

conical zone fanning out from the 12 hawk nests on treetops they observed. This, they say, is because of the way hawks hunt, swooping on prey including jays from higher up. This effectively envelops the hummingbird nests in a cone-shaped force field avoided by the jays.

However, when hawks abandoned their nests following raids by coatis, tree-climbing raccoon-like mammals, the jays became much bolder. They visited what had been no-fly zones and took more hummingbird eggs and chicks than when the hawks were around (*Science Advances*, doi.org/7hn).

Greeney doesn't think the hummingbirds consciously seek out the protection. "They simply return to sites where they've previously had good breeding success, and this happens to be under the hawk nests," he says.

Success for off-the-shelf stem cells

IT'S a quiet revolution. Simple stem cell therapies are finally making their way towards the clinic, and a treatment for wounds caused by Crohn's disease could be the first off-the-shelf therapy to get European Union approval.

Hard-to-treat wounds near the anus afflict around 50,000 people in Europe every year. In a phase III trial, a treatment developed by TiGenix in Belgium improved the

chances of healing such wounds by 50 per cent – and apparently with no adverse side effects.

The therapy uses stem cells derived from donated liposuction tissue, which have extremely low levels of the proteins that trigger immune reactions, says TiGenix head Eduardo Bravo. This means that the treatment, should it be approved after the full results are published next year, can be given

off-the-shelf – the stem cells from a single person could be used to treat 2500 people.

By contrast, the only stem-cell-based medicinal product that is currently approved for use in the EU – a cornea treatment – involves removing cells from each individual's eye and growing them outside the body for weeks. And bone-marrow transplants, which also involve stem cells and have been performed for decades, require a matched donor.

HIV 'pump' kills with ruthless efficiency

AFTER all these years, HIV can still take us by surprise.

Until recently, we thought HIV largely spread through the body as free-floating particles. Now we know that the virus can infect immune cells by being pumped directly from one cell into another, during brief connections between the two.

Research using newer tissue culture methods suggest that crucial white cells called CD4 T-cells are killed by this cell-to-cell transmission up to 95 per cent of the time (*Cell Reports*, doi.org/7fw). This mode of infection could be thousands of times more efficient than single viruses infecting cells from the blood.

This may help explain why efforts to develop HIV vaccines have so far proved fruitless. When viruses are inside cells, they may be more likely to escape destruction by antibodies, and to evolve resistance to them.

Supernova forge tested in the lab

DON'T try this at home. For the first time, a lab experiment has probed the nuclear physics inside a dying star.

When a star explodes, trillions of tonnes of gas collapse inwards before bursting into a supernova. As this happens, elements fuse to form heavier elements – but the details of the process are unclear.

A team based at Goethe University in Frankfurt, Germany, simulated the event by confining 100,000 ruthenium ions in a device called a particle storage ring, where the ions interacted with hydrogen. Sometimes they picked up a proton to become the heavier rhodium (*Physical Review C*, doi.org/7f8). The experiment can help to update models of how heavy elements are forged.

Crappy fashion keeps spider alive

THIS spider has gone to town in making itself look like crap – literally.

Bird-dung crab spiders spend a lot of time sitting motionless on leaves, using their gross looks to attract flies for dinner. Their trick is to mimic bird droppings in colour, shape, size and smell, deceiving predators and prey alike. “Birds, almost all with good eyesight, will not go for what appears to be their own turd for food,” says Joseph K. H. Koh of the Lee Kong Chian Natural History Museum in Singapore.

The spider’s body has a glossy surface that gives it the “wet” look of fresh faeces. “The nodules on the body and rough-edges of the legs further reinforce the ‘shitty’ look – pardon the rudeness,” Koh says.

Long Yu of Hubei University in China and his team exposed the spider to one of its predators – jumping spiders. They also added houseflies as prey. The team found that the camouflage helps these crab spiders (*Phrynarachne ceylonica*) repel more jumping spiders and attract more flies than those without camouflage. They presented their findings at the Behaviour 2015 meeting in Cairns, Australia, last month.

Other spiders, such as orb weavers in the genus *Celaenia*, also look like bird droppings, but the foul smell makes bird-dung crab spiders unique.



Key enzyme makes farm kids healthier

DIRT is good for you. Kids on farms are less likely to develop allergies and asthma than urban children. But the protective effects of friendly microbes also seem to depend on a person’s genetic make-up.

The hygiene hypothesis says that a lack of exposure to dirt and microbes is to blame for increases in allergies and asthma. One explanation is that children today encounter less endotoxin, a bacterial protein found on the surface of many common species, including *E. coli*, that may be

important for damping down overactive immune systems.

Children with gene mutations that disrupt the functioning of an enzyme called A2O are more likely to have asthma and allergies, so Bart Lambrecht of Ghent University in Belgium and his team wondered whether A2O may be involved in helping endotoxins train our immune systems.

First they exposed mice to endotoxin, and saw they developed fewer allergies when later exposed to dust mites. But this effect wasn’t seen when the

experiment was repeated with mice that had been genetically engineered to lack A2O (*Science*, doi.org/7hf). Lambrecht and his team then turned to human lung cells and found that A2O was less active in adults who had asthma.

“It’s important because it shows that endotoxin can’t work on its own,” says Erika von Mutius of the Ludwig Maximilian University in Munich, Germany, a proponent of the hygiene hypothesis.

It is thought that about 5 per cent of people have a faulty version of the A2O enzyme.

Palaeolithic people ate carbs as well

GOING on the palaeo diet? Don’t put down your porridge just yet. Hunter-gatherers ate oats as far back as 32,000 years ago – way before farming took root.

This is the earliest known human consumption of oats, say Marta Mariotti Lippi at the University of Florence in Italy and her colleagues, who made the discovery after analysing starch grains on an ancient stone grinding tool from southern Italy (*PNAS*, DOI: 10.1073/pnas.1505213112).

The Palaeolithic people ground up the wild oats to form flour, which they may have boiled or baked into a simple flatbread, says Mariotti Lippi.

They also seem to have heated the grains before grinding them, perhaps to dry them out in the colder climate of the time. Mariotti Lippi notes that this would also have made the grain easier to grind and longer-lasting.

This multi-stage process would have been time consuming, but beneficial. The grain is nutritionally valuable, and turning it into flour would have been a good way to transport it, which was important for Palaeolithic nomads, she says.



Speedier trains can slow down roads

READING this while stuck in traffic? Fast trains may be to blame. Slowing the London Underground could cut overall congestion in the city.

Marc Barthelemy of the French Atomic Energy and Alternative Energies Commission in Gif-sur-Yvette and colleagues mapped out the road and subway networks in London and New York City and simulated travel at different speeds. They found that the ratio of the average road and rail speeds can have a critical impact on congestion.

If the subway speeds up while road speed stays fixed, for example,

more people on the outskirts will use trains. But these commuters often have to travel by road to do so, as suburban stations are thinly spread. The result is more congestion overall, as increased traffic at the outskirts outweighs smoother flow in the centre (arxiv.org/abs/1508.07265).

“If you want to give more access to more people, then increasing the speed of the subway is not the best solution,” says Barthelemy – packing stations more closely is often better. New York City is an exception, however: congestion here is so bad that speeding up trains does help.

Automatic world

The technology behind bitcoin is creeping out into the real world, says **Jacob Aron**. The possibilities could change the way society is run

THE centre cannot hold. The rise of bitcoin took the right to issue money, once the sole preserve of governments, and placed it in the hands of everyone. Now a spin-off technology could do the same for other core concepts of society: identity, ownership, reputation and even the rule of law.

This technology is the blockchain, and it has the potential to enable the ultimate workers' cooperatives, or perhaps an ultra-libertarian parallel society, beyond governmental control.

Bitcoin's blockchain is a cryptographically secured list of every bitcoin transaction ever made. The list is stored on every machine running bitcoin software and is continuously updated as each transaction is completed. No central authority is in control: the machines essentially monitor each other to stop fraud.

But blockchains can be used for more than financial transactions. Last year saw the introduction of Ethereum, a blockchain platform that enables "smart contracts", which automatically enforce agreements between two parties. You can think of a bitcoin payment as a specialised kind of smart contract, in which one person agrees to pay another a certain sum; but smart contracts can govern any agreement that can be digitised.

Ethereum was fully launched last month with developer tools to build distributed apps, or dapps, on its blockchain, and a host of Ethereum-powered services are springing up. One of the most developed is Augur, in which users bet on the outcome of events, such as who will win the

US presidential election in 2016.

These kinds of prediction markets already exist – Betfair is the largest – but they are centralised, meaning that firms must handle money and rule on outcomes. Augur automates this, using smart contracts to gather

"Anything that requires proof of ownership can be replaced by the blockchain"

consensus on completed predictions and pay winners.

"At no point is a human being ever touching anybody's money, it's controlled by an algorithm and stored on the blockchain," says Peronet Despeignes of Augur. The blockchain stores the reputation of users, ensuring that anyone trying to cheat the system is swiftly booted out. The service will launch fully in the coming months.

Existing firms also see the blockchain's potential. Samsung and IBM are experimenting with Ethereum to control smart

devices (see "Our blockchain future", below), and banks such as Citi, UBS and Barclays, having seen the rise of bitcoin, are exploring the technology.

"The evolution of the blockchain is perhaps the greatest advancement of computer science since the invention of the internet," says Barclays' chief design officer Derek White. The bank has partnered with a number of start-ups and currently has 45 internal blockchain experiments. "Anything that requires proof of ownership through paper today can be replaced by the blockchain."

Parallel law

Smart contracts could even go beyond ordinary businesses, giving rise to autonomous entities that live on the blockchain. For example, Etherplan is working on software that is designed to replace wealth managers by automatically investing according to a customer's desired portfolio, then paying out to nominated



TOM SIBBLEY/GALLERYSTOCK

individuals. Once set up, it will keep going even after the initial customer has died, says founder Donald McIntyre. "If a customer disappears, and we disappear, the smart investment plans are going to continue executing their investment strategy and distributing to beneficiaries."

But how will these smart contracts interact with law in the real world? If I sell you my house by transferring ownership on the blockchain, but refuse to actually move out and hand over the keys, will the courts recognise that I have broken our agreement? At the moment, no one is quite sure.

"It's not recognised by law because it is meant to be a parallel law," says Stephan Tual of Ethereum. But if people start managing their affairs using blockchain law, governments will have to accommodate it, he says, just as the music industry had to

OUR BLOCKCHAIN FUTURE

The range of applications built on the blockchain is growing all the time. Here are just a few of the up-and-coming concepts.

ADEPT is a joint IBM-Samsung experiment for putting devices on the blockchain. Your washing machine could use smart contracts to order itself detergent.

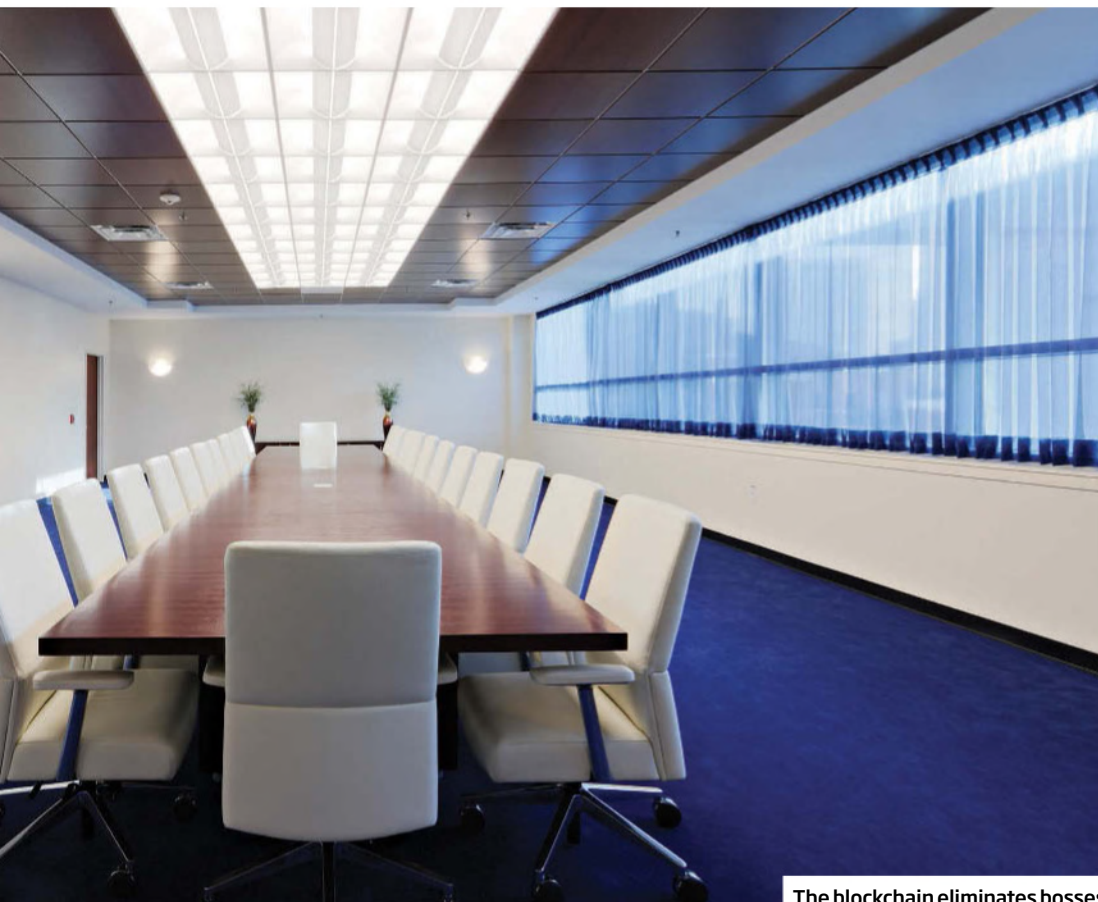
BoardRoom will let people run organisations on the blockchain, controlling secure votes and budgets from anywhere. Charities and governments could use it for ultimate

transparency, says founder Nick Dodson.

Everledger is working with Barclays to track the ownership of diamonds and combat fraud. There are plans to expand into other goods.

Provenance will reveal supply chains by recording the transfer of goods through businesses.

Finally, Slock.it provides internet-enabled physical locks on the blockchain, so you could email your keys to someone and revoke them at any time.



The blockchain eliminates bosses

adapt to file-sharing services such as Napster and BitTorrent. “These technologies force the existing environment to evolve.”

We’ve already seen that happen to some extent with bitcoin, with new laws put in place to manage its use. And two government-mandated blockchains are already under way: a digital currency register in the Isle of Man, and a land title registry in Honduras. Perhaps whole governments could one day run on the blockchain, like a town council that wants to provide transparency in its decision making.

“In order for value to be transferred across the blockchain in the future, there will have to be policy and regulation around it,” says White. Barclays has already started speaking to people in government about the way forward, he adds.

But as we have seen with

bitcoin, the blockchain is also well suited to illegal activity. Take Silk Road, the bitcoin marketplace for illegal drugs that was shut down by the FBI in 2013. Smart contracts mean that someone could build a distributed Silk Road and then step away, leaving the market to run itself. When autonomous software is facilitating drug deals, who do you prosecute?

Florian Glatz, a lawyer and consultant to blockchain start-ups, says that despite their name,

“Historically we’ve automated the workers, now we’re automating the bosses”

smart contracts are still software and not law, so traditional legal systems will still be needed for now. “The vision of this world where smart contracts rule supreme is really only possible if

the whole infrastructure is upgraded to obey whatever is written on the blockchain.”

Such a vision is a long way off, but it’s easy to see how the blockchain could take on other forms of organisation. The functions of the app-powered taxi service Uber – connecting drivers with riders and managing payments – can be translated into smart contracts, but so can the ownership of the firm itself. Drivers could own shares in an automated Uber-like cooperative and avoid the fees Uber currently charges them. It’s a reversal of the trend for technology to eat away at low-level jobs, says Tual.

“Historically we’ve automated the workers, now we’re automating the bosses.”

There’s an irony that tech disrupters such as Uber, which claim to bring power to the people by cutting out middlemen, could

themselves be disrupted by the blockchain, eroding their centralised power. “In Europe there is quite a big concern about the growing dominance of US tech giants,” says Despeignes. “Ethereum holds the promise of creating a new paradigm of decentralised applications that no one owns.”

Extreme capitalism

But autonomous organisations could equally concentrate power in the hands of a few owners – or even none. Some have floated the idea of a blockchain-powered self-driving car that takes fares and pays for its own upkeep. This extreme version of capitalism, in which the means of production own themselves, could leave the rest of us to be bossed about by machines.

That particular example seems far-fetched, as someone ultimately has to be liable when a car crashes, but the libertarian bent of the bitcoin community makes extreme capitalism a concern, says Glatz – no one seems to be interested in replicating the welfare state on the blockchain. “We’re building up this infrastructure where our core concerns are more and more irrelevant because they cannot be captured by software.”

This power struggle over the future of the blockchain will probably unfold just as the internet has, with companies, criminals and hardcore idealists all carving out their own corners of the technology. What remains to be seen is how the public will feel about passing some of the most important mechanisms behind society into the hands of everyone and no one at the same time. Bitcoin caught on thanks to the potential to get rich quick, but these newer blockchain concepts are less immediately appealing. “What’s going to be the catalyst that will drive the greatest adoption?” says White. “We don’t know yet.” ■

Therapist in my pocket

Smartphones can help you track your mood, says **Aviva Rutkin**

LIE down anywhere that suits: the world is now your therapist's couch. People with problems such as anxiety or mood swings are turning to smartphone apps for advice.

According to the US National Alliance on Medical Illness, 59 per cent of adults in the US with a mental health condition have not received relevant services in the past year. Smartphones could help make these services more accessible and affordable.

One app with this aim is PTSD Coach, which lets people discreetly screen themselves and learn more about the disorder. Another is Moodnotes, which keeps track of emotional swings and offers new perspectives on situations. And on Talkspace users can anonymously text a therapist and receive a response within the

next few hours, for a weekly fee.

More than 150,000 people have used Talkspace so far, says co-founder Oren Frank. For nearly half of them, it's their first brush with therapy. "Therapy becomes a daily experience, much more in tune with what happens to you on a daily basis," he says.

"People can anonymously text a therapist and receive a response within the next few hours"

This week, another app in this vein debuts. TruReach Health offers free lessons in cognitive behavioural therapy, a treatment that teaches people to recognise and alter negative patterns in their thoughts or behaviours.

The lessons are given in short animated videos and between

watching these, users practise what they have learned by jotting down their thoughts in a digital journal. The app will be tested at Royal Ottawa hospital in Canada and in trials with students at a nearby university.

TruReach Health was created by Jeff Perron, a clinical psychology graduate at the University of Ottawa. He says the app isn't meant to replace face-to-face therapy, but to provide a substitute for those who don't have access to it – whether for fear of social stigma or simply the expense.

"I love psychologists. If everyone could go and see one, then we'd all be better off, but that's just not possible," says Perron. "We're giving someone a tool because, 99 times out of 100, they just don't have access to face-to-face therapy."

Digital therapy may not be as outlandish as it sounds. The UK National Institute for Health and Care Excellence recommends certain cognitive behavioural therapy programs for people with mild depression or anxiety.

Artificial intelligence could be involved too. In May, Talkspace teamed up with the engineers behind IBM's Watson system to find ways to utilise the wealth of message data they have generated since launching in 2012. The team hopes to build an algorithm to match new users to the therapist who would suit them best.

Talkspace is also collaborating on an even more ambitious project: a kind of crowdsourced therapist. This program would look at what a person receiving therapy types into the system, comb through Talkspace's archives and then present the therapist with a suggested response.

"If it can be done, it will be amazing," says Frank. ■



Zap to stop puking

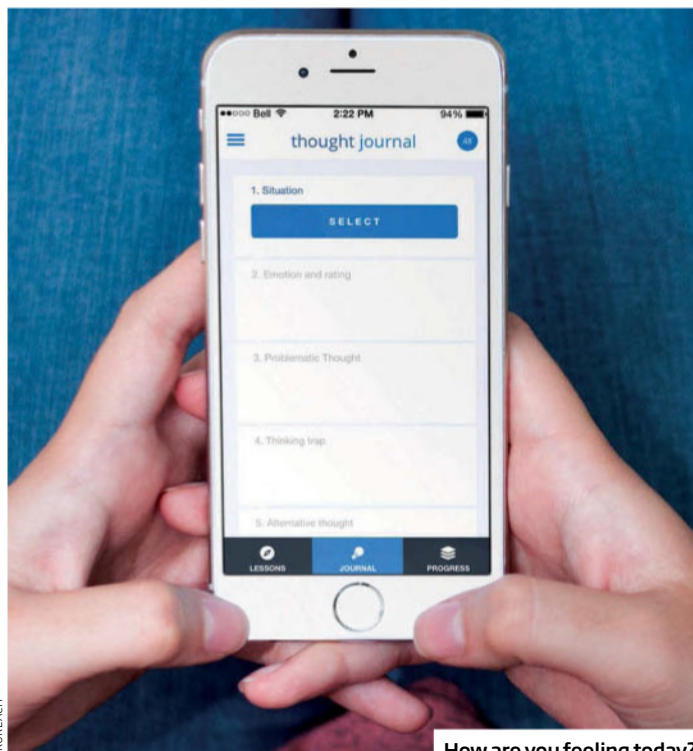
A brain zap could stop motion sickness. A team at Imperial College London put volunteers in a special chair designed to make anyone motion sick within minutes. Half wore a cap that applied an electric current to dampen responses in the brain area that deals with balance. They lasted much longer than the others before feeling sick (*Neurology*, doi.org/10/7hm).

"The app was conceived to help the business of reading, not to make the reader go 'wow'"

Ian Pears on his new novel *Arcadia* which is designed to be read on an app. The app helps readers navigate the novel's complex structure and lets them choose what order to read it in.

Starfish killer

It's payback time. A robot with a lethal injection will seek and destroy the crown of thorns starfish that eat coral on the Great Barrier Reef. A team at the University of Technology Sydney used photos and video to train their robot to recognise the starfish. It has completed its first swim and will be tested on the reef later this month.



How are you feeling today?

TRUREACH

DAVID GEE / ALAMY STOCK PHOTO

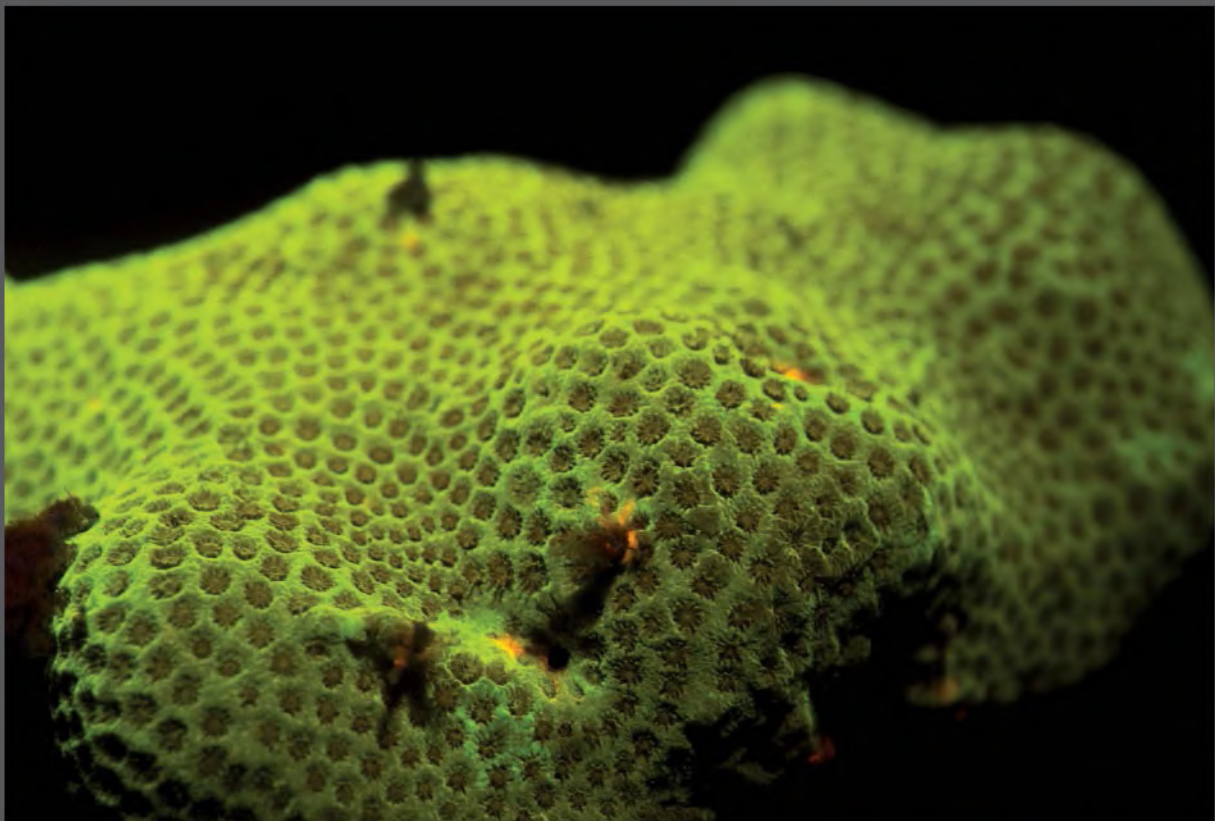
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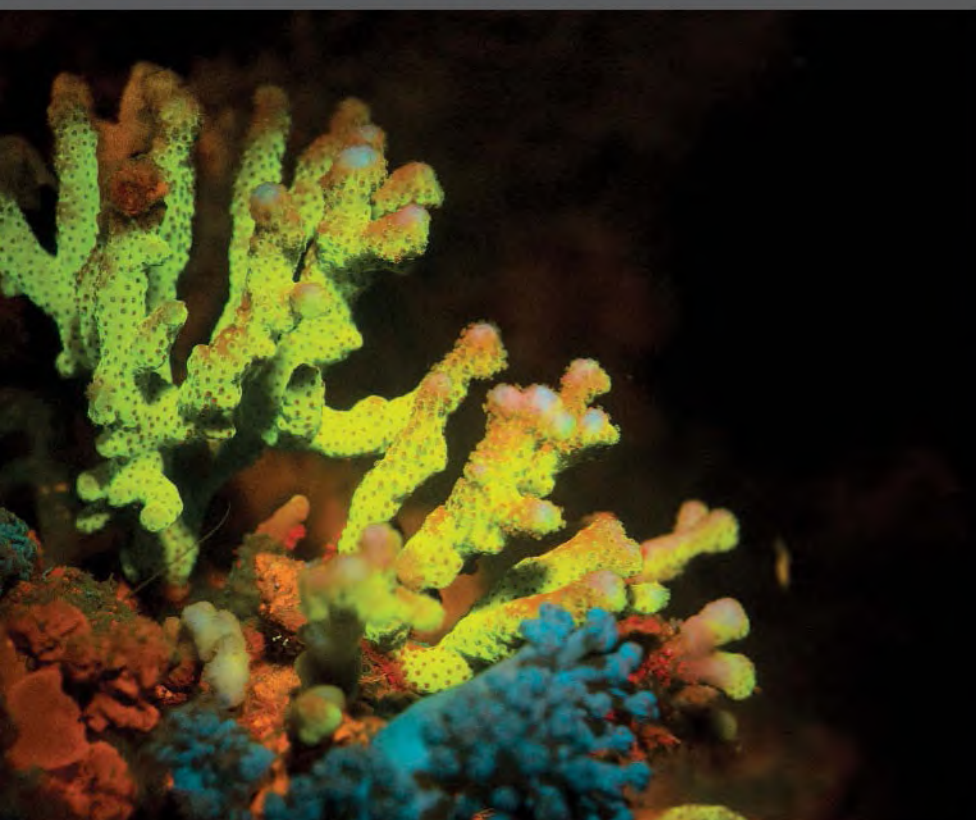


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Underwater rainbow

LIGHTS, camera, fluorescence! The combination of all three allowed German underwater photographer Oliver Meckes to produce these vibrantly colourful shots of corals, anemones and other Red Sea creatures in the dead of night.

When viewed with the naked eye, the organisms barely appear to have any colours at all. But when they were bathed in bright blue light from the lamps that Meckes took with him to the sea floor, they gave off the colours seen here through a natural process called fluorescence.

Shorter wavelengths of the light spectrum, such as blue light, penetrate further into the ocean depths than longer wavelengths, such as red light. These creatures, which are found at depths below 15 metres, naturally absorb the small amounts of energy from the blue sunlight that reaches that far down. They then emit the remaining energy at a different wavelength, but too faint to be visible.

By bringing down his own intense source of blue light, Meckes can make the marine animals and plants fluoresce much more brightly than usual, enabling him to capture these amazing shots. He calls the procedure "fluo-diving".

In coral, the fluorescent colours are caused by proteins that are produced by the organism and by algae that live within it symbiotically. One theory is that the absorbent proteins serve as a kind of sunscreen, shielding the coral from more harmful wavelengths of sunlight that penetrate the depths. Another is that they offer camouflage against predators. But whatever the reason, Meckes says that they turn the sea floor into an underwater rainbow. Andy Coghlan

Photographer

Oliver Meckes

Eye of Science/Science Photo Library

Liberate the scientists

Our economic well-being relies on scientific innovation, so why are we stifling radical research, asks **Donald Braben**

AT THE turn of the 19th century, the world stood poised for one of its greatest transformations. An increasing ability to apply the fruits of science to everyday needs created a priceless new paradigm for advancing humanity.

In the decades that followed, as we worked out how to better manage this process, we began to emerge from the stagnation and suffering that marked preceding centuries. Economic growth exerted its life-enhancing magic.

The industrial revolution in the UK sparked social changes that eventually spread far beyond its shores and steadily transformed standards of living, at least for the industrialised parts of the world.

Unfortunately, progress seems to have slowed recently, and the industrialised world might be heading for stagnation once more. Why? To answer that, we need to understand the origins of economic growth.

For years, economists assumed growth came from increases in the triple alliance of labour, capital (basically equipment to produce goods and services to trade) and resources. Growth would follow as populations and trade increased, and new sources of minerals such as coal, gold and oil were discovered.

Economist Moses Abramovitz was among the first to cast doubt on this claim. He found that although US national output per capita had essentially quadrupled over eight decades up until the mid-20th century, changes in labour and capital accounted for only 10 per cent of that growth.

In 1950, Robert Solow at the



Massachusetts Institute of Technology examined the US economy between 1909 and 1949. He, too, tried to reconcile growth data with increases in the triple alliance, but could not.

Ironically, economists had expected that the part of growth not explained by labour, capital and resources would be small. Accordingly, they named it “the residual”.

Solow, introducing a “new wrinkle”, concluded that the bulk of growth – seven-eighths, in fact – came from technological advances (better machines, not more of them, for example). Thus, the triple alliance, long assumed to be humanity’s sole benefactor,

had played only a minor role.

Solow was awarded the Nobel prize for economics in 1987 for his remarkable discovery. Unfortunately, research funding agencies today seem to have forgotten his lessons.

Capitalism, the ideology behind all industrial and commercial enterprise for centuries, demands incessant growth. Amazingly, for much of the past century – and despite crises and wars – science has risen to those demands, but seems to have failed to do so over

“One key obstacle is the use of peer review for deciding what research gets funded. This is deluded”

the past few decades. We now have a tiger by the tail. If we cannot find viable alternatives to capitalism that offer increased living standards for the majority, we must ensure that we have an adequate flow of technological change to appease the gods of growth.

If we do nothing, we will soon fall back into the stagnation that humanity has often had to deal with. The signs are not good. Bureaucracy and red tape are slowly strangling us.

How can increased growth be fostered? Global expenditure on R&D is estimated at \$1.6 trillion annually, which suggests no dearth of commitment. However, the governance of scientific research is now dominated by the pursuit of nitpicking efficiency and the elimination of risk. Funding agencies have preconceived ideas about what they are looking for and accordingly view the future as predictable. Their attempts to manage creativity only seem to result in its curtailment.

One key obstacle is the use of peer review as the gold standard for deciding what research gets funded. This is deluded. Although peer review might work for the mainstream, it excludes radical departures in thinking.

The kind of blue-skies research that we need more of, driven by curiosity, has suffered in a world that prioritises practical answers and value for money. In the UK, blue-skies funding is in decline at most research agencies. The backdrop to this is a prolonged period of budget freezes and

spending reviews that seek to cut public expenditure further, as a goal-oriented ethos and short-termism become more entrenched. None of this encourages the freethinking research that led to many major breakthroughs in the past.

The enforced conservatism surrounding research priorities substantially lowers the chance of major discoveries and contributes to the problem of feeble growth. Unless we restore total freedom to the few academics who can make good use of it, the outlook for civilisation is bleak.

The problem is who to fund. The truly great 20th-century discoveries were made by some 500 researchers working on problems they had selected. Almost all were academics who made serendipitous discoveries, and many won Nobel prizes. They are members of what I call the Planck Club after physicist Max Planck, who discovered in 1900 that energy was quantised. They also transformed economic growth, and it is imperative that we find new sources of funding for their successors. It represents an ideal opportunity for investors, provided they realise that the work of the few they bankroll cannot be predicted or controlled.

In 1980, energy giant British Petroleum set up such an initiative, its Venture Research unit, which I led. It ran until 1993, and its modest £20 million outlay over that period supported 37 research groups with radical ideas that mainstream peer review would have rejected. It created at least 14 breakthroughs.

Something akin to this must be repeated if we are to rekindle the progress of the past. ■

Donald Braben is an honorary professor in Earth sciences and in the office of the Vice-Provost for research, University College London. His latest book is *Promoting the Planck Club: How defiant youth, irreverent researchers and liberated universities can foster prosperity indefinitely* (Wiley)

ONE MINUTE INTERVIEW

Guns that fire only for you

The US gun control debate is gridlocked, but new technology can help prevent needless deaths, says **Margot Hirsch**



PROFILE

Margot Hirsch is president of the Smart Tech Challenges Foundation, based in San Francisco, which awards funds to innovators to foster developments in firearm safety

What is your foundation's approach to the US gun situation?

It's a polarising issue in this country – the political system is gridlocked. Many groups pursue a legislative approach to gun violence, but we've sidestepped the politics to address the problem through technology. Last year we launched a \$1 million challenge to invite innovators, the majority of whom are gun owners themselves, to create safety devices that can be built in to new guns – or retrofitted to existing ones, because the US already has about 300 million guns in circulation.

What have they come up with?

We are now funding 15 innovators who are working on a wide range of gun-locking devices, such as biometric technologies that use a fingerprint or grip that is unique to an individual to verify their identity, so the gun can only be fired by authenticated users. We also have people developing radio-frequency identification (RFID) technology. These guns can only be fired when in close proximity to an RFID token, which could be

worn in a ring or bracelet. If the quarter of a million or so guns that are stolen out of US homes every year incorporated such safety features, these weapons would essentially be rendered useless if they fell into the hands of criminals who might otherwise hurt someone with them.

Under normal conditions, how fast could your fingerprint unlock a gun?

One of our innovators has created a prototype biometric retrofit for an AR-15 Bushmaster rifle. It reads your fingerprint in a fraction of a second and unlocks the gun. It's pretty much instantaneous. If your hand gets wet, dirty or bloody there may be issues around reading the fingerprints quickly enough, but the technology is always improving.

Interesting that you work with gun owners...

They want to reduce firearm injuries and deaths, too. There are 1.7 million unlocked, loaded guns in US homes. That's a huge concern because children are innately curious, and oftentimes in homes with firearms all the guns are locked up except for one – the one used for personal protection in case someone breaks into the house. It's hidden away in a bedroom, say, loaded and ready to be used in an emergency. But children have a tendency to find things and, before you know it, the child finds the gun, is playing with it and accidentally fires it, injuring or killing the child, a friend or a loved one.

Why aren't more groups developing such safety technology?

There's not a lot of funding for projects like this. For example, the Kickstarter crowdfunding website doesn't let you apply to fund anything to do with weapons. And people who want gun control tend to pursue legal means. We continue to have these tragic shootings in the US, but I hope our work will further the development and funding of these technologies so that ultimately we will see smarter, safer firearm products get to market and start saving lives.

Interview by Sally Adee

Death and pain of a digital brain

One day we will create virtual minds. Could this simulation suffer, asks **Anders Sandberg**, and does it matter?

I turned off the computer as I left my office, deleting the neural network simulation that I had been working on. Then a thought hit me: had I just killed something? I rationalised that the simulation was simpler than the systems within the bacteria I was doubtlessly squashing on the floor. If they did not matter, neither did it. But the doubt remained...

SCIENCE has a problem. If we want to find out what really happens in living beings, or how to cure diseases, often we must experiment on them. Digital simulations offer a way out.

Ever since the squid giant axon was modelled in the 1950s using a mechanical calculator, our ability to simulate biological systems has skyrocketed. Today we can run neural simulations on supercomputers that contain hundreds of millions of realistic neurons and billions of synapses. Cells and their chemistry have been modelled to a similar extent. This potentially offers an alternative to animal experiments. Instead of subjecting a living creature to pain when testing a painkiller, why not simulate the pain system and check whether the treatment works? The logical endpoint of this is an emulation, where every part of the brain – and body – is simulated digitally.

The challenge is to map the connectivity in real brains. It will be years before we can create even a proper insect brain, but work is already under way to create the brain of the nematode worm *C. Elegans* in virtual form. The worm is a good candidate for this because it has one of the simplest brains of any organism, with just 302 nerve cells. In 2012, researchers at the University of Waterloo, Canada, announced the creation of a large functional brain simulation, SPAUN, with 2.5 million neurons.

And the Human Brain Project, a European collaboration, has the ultimate aim of simulating a whole human brain.

Although these digital emulations could resolve many existing ethical dilemmas, they raise new ones. The first is that many real animals must be sacrificed to create a virtual one. We may one day scan the final lab rat, which will become Standard Lab Rat 1.0, and rely on simulation from then on – but there will have been years of basic neuroscience to enable that simulation. The second problem is that we need to be certain our simulations are right if we want to trust them with our drug testing or other research.

It is the third problem that really interests me. Would emulations feel pain? Do we have to care for them like we do for animals or humans involved in medical research?

This hinges on whether software can suffer. For example, Sniffy the Virtual Rat lets users observe the behaviour of rats given electric shocks to teach the psychology of learning without using live animals. Yet few of us would think there is any real pain there: it is essentially an interactive cartoon, similar to a virtual pet toy. We may empathise with it, but it is similar to a talking doll. Whole brain emulations, which recreate the neural connections of animals and even humans, are a different matter.

In his 1978 paper “Why you can’t make a computer that feels pain”, philosopher Daniel Dennett argued that we don’t have a rigorous enough definition of pain, so we cannot build a machine that feels it. But he also believed that we may eventually figure it out, and at some point thoughtful people would refrain from kicking robots. Other philosophers, such as John Searle, have argued that no matter how

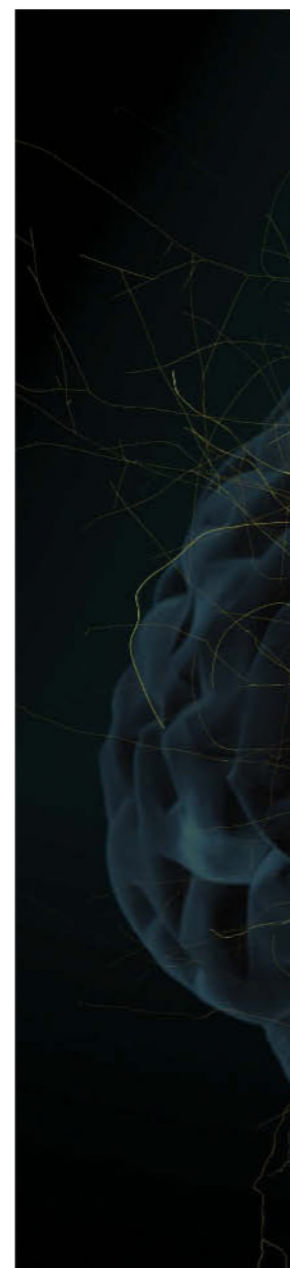
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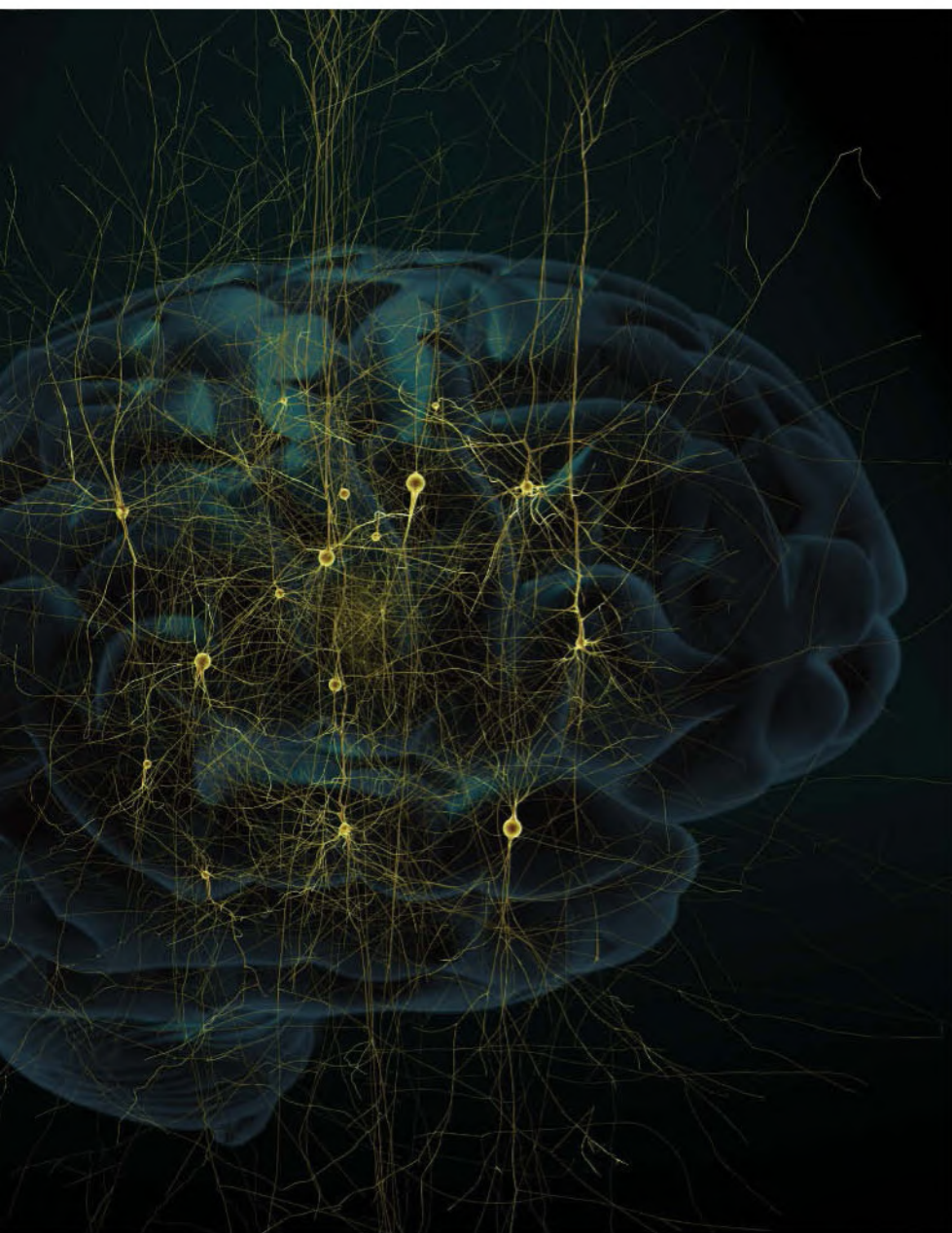
Anders Sandberg researches the societal and ethical issues of human enhancement and new technologies at the Future of Humanity Institute, Oxford Martin School, University of Oxford. Find out more at aleph.se/andart2/

Digital mind: one day a copy of your brain could be replicated in a computer

sophisticated the simulation is, it will always be mere numbers updated in complicated ways: there cannot be real intentions or consciousness in pure software. It might also be that the system needs to have a body to ground it in the real world.

But what about CyberChild, created by the neuroscientist Rodney Cotterill as a model of his theory of consciousness? It is a virtual simulated infant with a brain and body model based on real biology. It has internal states such as blood sugar levels, and activity in different brain areas. It responds to these





internal states, it can learn, it needs food – if its nutrient levels are too low it “dies” – and it can cry and flail its arms. Yes, it is a very simple organism, but it is intended to be conscious. There is something eerie about it: assuming Cotterill’s theory is right, in principle this being could have experience.

We know brains exist for motivating actions that lead to better outcomes for the organism: this is the whole point of pain, pleasure and planning. If we were to make a perfect copy of the activity of a brain, we would get the same behaviour, based on the same pattern of

internal interactions. There is no way of telling from the outside whether it has any real experience, whatever that is. There is considerable disagreement about whether software can suffer, or whether it matters morally. So what should we do?

My suggestion is that it is better to be safe than sorry: assume that any emulated system could have the same mental properties as the organism or biological system it is based on, and treat it accordingly. If your simulation just produces neural noise, you have a good reason to assume there is

nothing in there to care about. But if you make an emulated mouse that behaves like a real one, you should treat it like you would treat a lab mouse.

I agree this is inconvenient for computational neuroscience. But it is probably the moral thing to do. Once we get to simulated vertebrates, we ought to apply government animal-testing guidelines. We should avoid generating virtual suffering by not running experiments that produce pain signals. But we can also improve on biology, because in simulations we can (temporarily) leave out pain systems, simulate perfect side-effect-free painkillers or just block neural activity related to suffering. We could in principle monitor the emulated brain for any kind of suffering and stop as soon as

“Turning off the neural network simulation, it hit me: had I killed something?”

we detected it. There is also the issue of quality of life. We have begun to recognise that giving animals good environments matters; building equally good virtual environments may prove a hurdle. Virtual rats would plausibly need virtual fur, whiskers and smells to feel at home.

What about euthanasia? Living organisms die permanently, and death means the loss of their only chance at being alive. But an emulated brain could be restored from a backup: Lab Rat 1.0 would awake in the same way no matter how many copies had been tested in the past. The only thing lost when restoring it would be the memories of the previous experiment. There may still be pleasures and pains that count. In some ethical views, running a million supremely happy rat simulations in the background might be a “moral offset” for doing something painful to one.

In the long run I believe we will create human brain emulations. Their moral status will in many ways be easier to determine than for animals: just ask them. Take an eminent philosopher doubting software can be conscious, scan their brain, and ask the resulting emulation if it feels conscious. If the response is: “...yes. Darn. I need to write a paper!” we have pretty good evidence that there is a being with enough intellect, introspection and moral value to deserve rights. But until then we should treat our software animals well. Just in case. ■

A HUMAN BRAIN MODEL OVERLAIN WITH A STYLIZED NETWORK OF NEURONS. © BBP/EPL 2014.

Elements at the extreme

The chemistry we see at Earth's surface is not even the half of it, says **Matthew Chalmers**

IT IS chemistry's poster child. From copper's conductivity to mercury's mercurial liquidity, the periodic table assigns the chemical elements to neat columns and rows and so reveals their properties. It is chemists' first reference point in all their endeavours, whether building better catalytic converters, making concrete set faster or looking for the best materials for medical implants.

Yet this iconic picture of science is hopelessly parochial. Most of the known matter in the universe doesn't exist under the cool, calm conditions of Earth's surface that the periodic table assumes. By mass, more than 99.9 per cent of normal matter resides within planets and stars – environments of high temperatures, but above all unimaginable pressures.

Here, the elements' familiar identities start to blur. "We essentially have a new periodic table at high pressures," says materials scientist Paul Loubeyre of the Alternative Energies and Atomic Energy Commission (CEA) in Bruyères-le-Châtel, France. As yet, this high-pressure realm is one we know little about – proportionally as if, in thousands of years of Earth exploration, geographers had mapped out a region no larger than Spain.

Slowly, however, modern-day alchemists are ratcheting up the pressure. As they do, they are transforming the familiar physical and chemical properties of elements from hydrogen to iron, turning liquids to solids, non-metals to metals and more besides. The aim is not just to understand more about the deep chemistry of our planet and others, but also to find materials that react more efficiently, store energy more effectively, or even perform that most yearningly sought-after of tricks: conducting electricity without resistance at room temperature.

Electron squash

It was the Russian chemist Dmitri Mendeleev who, back in 1869, produced the first recognisable periodic table. He showed that patterns begin to emerge in the properties of the chemical elements if you order them by their atomic weight, and used those patterns to predict the existence of undiscovered elements. But it wasn't until the advent of quantum mechanics in the 20th century that those patterns were explained. Electrons circling an atom's nucleus can only occupy discrete "orbitals", each of which accepts a

strict number of electrons. The distribution of electrons within these orbitals – especially the outermost ones – determines an element's chemical character.

There are still niggles about the periodic table's validity under normal conditions (*New Scientist*, 12 July 2014, p 38), but turning up the pressure changes things entirely. Atoms get squished, deforming the "unit cells" that define matter's basic scale. Electrons squeeze into tighter orbitals, overlapping and forming more exotic configurations, and begin making chemical bonds with electrons in other atoms in entirely different ways.

Carbon provides a familiar example of the changes that can result. Coal is carbon formed from plant debris, compacted and heated for millions of years a few kilometres below ground. But go 100 kilometres or so down, and the high temperature, along with pressures 30,000 to 50,000 times those at Earth's surface, transform carbon's bonding to make an apparently different substance: diamond.

Occasionally, geological processes fortuitously bring diamonds closer to the surface, where they can be mined. Since the 1950s, however, researchers have been cutting out the billion-year geological middlemen. ➤



Journey to the centre of the Earth

The deeper you go towards the Earth's centre, the higher the pressure – and the weirder the chemistry

Large hydraulic presses weighing tens of tonnes now compress carbon to yield synthetic diamonds used in coatings, cutting tools and even jewellery.

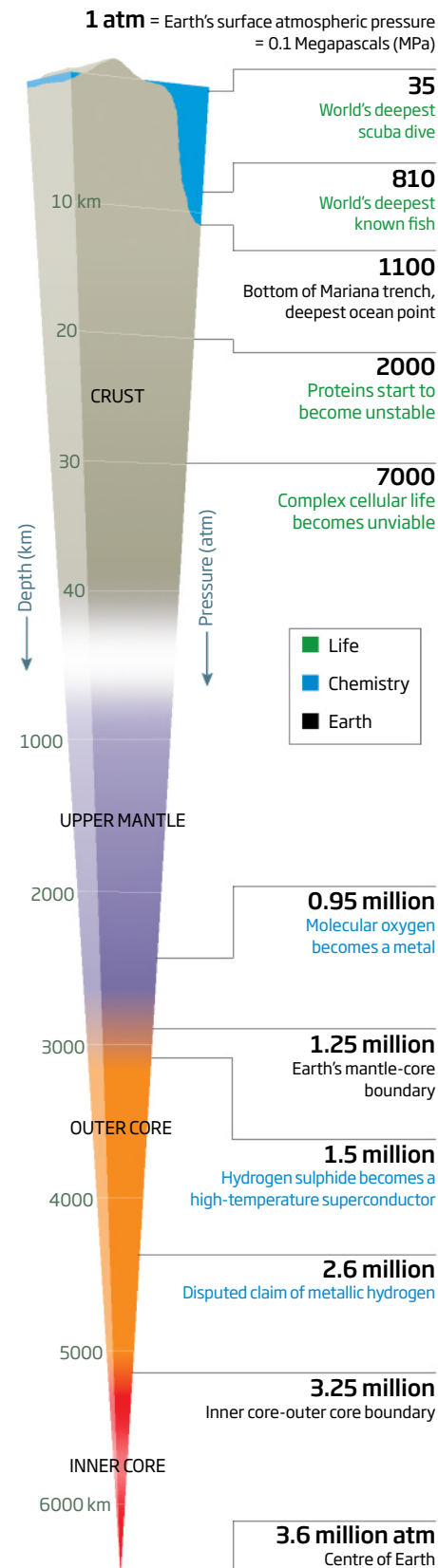
But even these pressures are tiny compared with those deep in Earth's interior (see illustration, right). For a more complete picture of the planet, we'd love to track what goes on in this high-pressure realm. "Stuff is moving and reacting, causing fluxes in different elements such as carbon, and this has relevance for climate change over geological history and theories about the origin of life," says geochemist Catherine McCammon of Bayreuth University in Germany.

Diamond to the core

With no direct access to such depths – our deepest drilled hole, the Kola Superdeep Borehole, penetrates just 12 kilometres beneath the north-west tip of Russia – simulating the pressures found there requires some cunning ruses. As anyone who has stepped on a polished wooden floor wearing high-heeled shoes knows, force concentrated into a small area produces very high pressures. A device known as an anvil cell takes advantage of this fact, producing the same effect as a monster hydraulic press by crushing tiny samples between two high-heel tips made of extremely hard materials.

Tungsten carbide is one such material, capable of delivering pressures equivalent to those in Earth's upper mantle. Diamond tips go further, to pressures found in Earth's core. They are also transparent, allowing researchers to observe in real time what happens as materials are crushed.

Even so, to really see what is going on at the atomic level requires special illumination: the intense beams of X-ray light produced at synchrotron accelerators such as the European Synchrotron Radiation Facility (ESRF) in Grenoble, France. McCammon and her colleagues recently placed their diamond anvil cell in the ESRF's beams to address the puzzle of Earth's core consistency. The core generates Earth's magnetic field, and is mostly made of iron. But the way seismic waves pass through it suggest the core has a consistency rather like tyre rubber – which is not what pure iron looks like under pressure. When mixed with carbon graphite powder and compressed, however, the researchers found iron forms an entirely different crystalline phase that mimics this plasticity, suggesting Earth has a vast, previously unknown carbon reservoir (*Nature Geoscience*, vol 8, p 220). Similar experiments



have also recently yielded new estimates for iron's melting temperature under pressure, leading to the conclusion that the temperature of Earth's inner core is 6000 °C, some 1000 degrees hotter than previously thought.

Iron's large number of orbiting electrons make it particularly difficult to model under pressure. Undaunted, researchers such as Loubeyre are moving on to even more complex elements, such as the rare earths. These materials are essential for technology from screens for smartphones to magnets for wind turbines, and the hope is that exploring high-pressure forms will allow us to better exploit their properties.

This same motivation holds for simpler elements, too – and it's here that the surprises have been greatest. Exert a pressure akin to those found in Earth's outer core, and sodium – a soft, highly reactive metal at Earth's surface – becomes transparent and something between a semiconductor and an insulator. Oxygen, meanwhile, turns into a solid metal at similar pressures, and if then cooled becomes a superconductor – in other words, it conducts electricity with no resistance.

The dramatic nature of these changes has caught many on the hop. "There have been simple rules guiding this field, but it turns out these things were wrong," says Loubeyre. "We are seeing baffling changes in unit cell volumes and remarkable electrical properties that are highly promising for applications."

Perhaps the most promising is the simplest atom of all: hydrogen. This is the universe's most abundant element, consisting of just a single electron orbiting a single proton. It is a bit of a misfit in the periodic table, generally sitting uneasily above lithium and sodium at the top of metallic group 1.

Calculations since the 1930s have indicated that high pressures would indeed turn hydrogen into a metal, squeezing the electron out of each proton's orbit and leaving them free to conduct. Not only that, but calculations suggested that the electrons' skittish interactions with the lattice of proton cores might at some point allow them to team up and pass through the solid hydrogen unimpaired – hydrogen could be made a superconductor. That might even occur at room temperature and potentially persist even when the pressure is taken off, just as diamonds retain their structure at lower pressures.

This would be a trillion-dollar transition. The highest temperature so far seen for a superconductor, a copper-based compound called a cuprate, is -140 °C at ambient pressure, and -110 °C at high pressures. A room-

temperature superconductor could allow the transmission of energy over distance without loss at a much lower price, transforming the electricity grid and consigning the internal combustion engine to history.

No one is sure at what pressure hydrogen's metallic and superconducting transitions might occur, although it seems likely that a metallic, although not superconducting, state makes up the core of Jupiter and other gas-giant planets. That's tough to replicate: the pressure at Jupiter's centre is 4000 gigapascals (GPa), more than 10 times that in Earth's inner core and 40 million times greater than at Earth's surface.

In 2011 Mikhail Eremets and Ivan Troyan of the Max Planck Institute for Chemistry in Mainz, Germany, reported a metallic transition in hydrogen compressed to just 260 GPa in a diamond anvil cell (*Nature Materials*, vol 10, p 927). The claim was met with scepticism, and later analysis suggested they had probably found something subtly different: a poorly conducting semi-metal state (*Physical Review B*, vol 88, p 045125).

Still, just last month Eremets and Troyan

"A room-temperature superconductor could consign combustion engines to history"

pulled off something close to the desired trick with hydrogen atoms in a slightly more complex chemical form. They compressed hydrogen sulphide – that smelliest of gases, which gives off a strong whiff of rotten eggs – to just 90 GPa and transformed it to a solid metal. Taken to 150 GPa, it seems to become a superconductor when cooled to just -70 °C, the highest temperature ever recorded for a superconductor (*Nature*, DOI: 10.1038/nature14964). This superconductor also seems to work by a conventional mechanism that has been understood for 50 years, in contrast to the still-mysterious workings of the cuprates.

Pure hydrogen still remains the ultimate goal – after all, says Patrick Bruno of the ESRF,

the discovery of metallic hydrogen would probably be worth a Nobel prize. Besides a potential room-temperature superconductor, metallic hydrogen might form the basis of a revolutionary fuel technology: the molecular bonds of pure hydrogen are broken at high pressure, leaving a system that can store a huge amount of chemical energy.

There are still high-pressure depths to plumb to get there. "Recent work on sophisticated simulations cast doubts that there is any metallic state below 400 GPa – the current edge for experimental studies," says Eremets.

Loubeyre and his colleagues are working with a two-stage anvil – essentially a diamond crushing a diamond crushing something else – that lets them achieve pressures of 600 GPa, and he is confident of results soon. "Metallic hydrogen will probably be discovered in the next two to three years," he says.

Meanwhile new pressure records continue to be set – most recently osmium, Earth's least compressible metal, crushed at 770 GPa. As we progress we are beginning to find out just how much the 99.9 per cent of chemistry we don't see differs from the 0.1 per cent we do. Our techniques currently limit us to observing the properties of small samples of high-pressure materials, but the hope is that better synchrotrons, for example, will allow us to observe and perhaps even mimic the chemical reactions between different compounds that must go on deep beneath our feet.

That truly would be an eye-opener. Chemists already know and routinely exploit the transformations in chemical reactivity that even relatively small pressure increases bring. Molecular nitrogen in the atmosphere, for example, is a thankfully unreactive gas. But up the pressure 200-fold, and it readily reacts to make the fertiliser ammonia – the basis of the Haber-Bosch reaction that, by transforming agricultural productivity, has fed many a hungry mouth since the early 20th century. With such successes in mind, the pressure's on to discover more. ■

LIMITS OF LIFE

While researchers strive to recreate pressure extremes in the lab (see main story), human physiology fixes us firmly in a very thin shell of survivable existence. With training, we may reach Earth's highest points without breathing machines to assist with the thin, low pressure air. In water, rapidly increasing pressures limit even the most highly trained divers to a hundred or so metres.

But in general, Earth's life seems strangely pressure-resistant. Fish have been sighted by submersibles at depths of over 8000 metres, while the deepest microbial life found to date lies some 11 kilometres beneath the ocean surface in the Marianas and Tonga trenches, at pressures of 110 megapascals (MPa), some 1100 times those at Earth's surface.

Lab experiments suggest complex life becomes unviable if you go much deeper. The complex molecules used to make cells start to disintegrate at 200 to 300 MPa, and between 700 and 800 MPa even the most resistant biomolecules cease to function. Weirdly, though, some simple bacteria such as *E. coli* and *Shewanella* appear to resist pressures up to four times as high as this, and certain seeds, spores and freshwater

shrimp eggs have been shown to resume normal behaviour after being subjected to even higher pressures. "Take a seed, squeeze it to 75,000 atmospheres (7600 MPa) and it can still sprout, although the plant might look a bit different," says chemist Paul McMillan of University College London. "We don't really have a clue what is going on."

And with unicellular bacteria at least, survivors from one high-pressure experiment are able to resist even higher pressures in subsequent steps. Perhaps, says McMillan, that's because the DNA of the survivors contains protein-generating domains that help confer extreme pressure-resistance – which could give a clue as to their ultimate origin. "Maybe these could even be related to a distant past where life began in a deep rock-hosted environment, or sheltered there when the young Earth was blasted by asteroid impacts," he says.

As things stand, it seems temperature, rather than pressure, is the main limitation to life on Earth. "If life were present on other planets or satellites that remain colder at depth, then the laboratory results reveal that organisms could survive at even more crushing pressures," says McMillan.

Matthew Chalmers is a freelance writer based in Bristol, UK



March of the Red Devil

A fierce predator from the deep is taking over the eastern Pacific with extraordinary feats of transformation, finds Michael Tennesen

IN 1940, author John Steinbeck and biologist Ed Ricketts took a trip from the Californian city of Monterey, across the Mexican border and into the Gulf of California to survey the intertidal zones around its shores. In 2004, William Gilly of Stanford University and a team of graduate students retraced the voyage to draw attention to a changing world.

Where Steinbeck and Ricketts had found large sea snails, Gilly's crew found only smaller or dead specimens. Where Steinbeck and Ricketts had seen schools of tuna, marlin, sailfish and swordfish, Gilly's expedition sighted few. The Gulf of California, formerly

known as the great Cortez fish trap, has seen a massive decline in fish and shellfish in recent decades. Most fishermen will attest to it.

The thing that fascinates Gilly is what is replacing these dwindling species. Near San Pedro Martir Island he found a little pocket full of life – plankton, fish, squid and sperm whales. As the boat drifted over 1000-metre deep waters, the group was greeted by an incessant stream of Humboldt squid darting toward the boat and flashing their underbellies red and white. “This was a profound and qualitative change,” says Gilly, referring to the new and vast squid population.

Adult Humboldt squid (*Dosidicus gigas*) are roughly the size and weight of an adult human, have eight arms, two long tentacles covered with toothed suckers and are notoriously aggressive (see “Humboldt squid facts”, p 34). They will fearlessly latch on to divers with their powerful arms.

They aren't the largest squid in the sea, but deserve your attention for another reason. While many ocean dwellers are suffering as climate change makes waters warmer, less alkaline and less oxygenated, these beasts thrive and push into new territories. Recent observations suggest that this is all down to



“When pulled from the sea they flash an angry red and flail muscular tentacles”

extraordinary feats of transformation.

You may have heard of Humboldt squid under a different name. Some people call them jumbo flying squid, contrasting with the larger colossal squid and giant squid. Mexican fishermen call them *diablos rojos* – red devils. When pulled from the sea they flash a deep, angry shade of red and flail muscular tentacles. Underwater, they use their two tentacles with barbed suckers to capture passing prey in a flash and pull them to their arms and parrot-like beak.

Until a few decades ago, Humboldt squid were mostly found off the coast of South

America in the Humboldt current, which flows from the southern tip of Chile to northern Peru (see map, p 35). There are scant references to them in the Gulf of California before the 1960s. A thriving fishery for the squid developed in the Gulf during the 1990s, growing from almost nothing in 1993 to upwards of 110,000 tonnes between 1995 and 2009. They first appeared in California’s Monterey Bay in 1998, coinciding with a strong El Niño event that swept warm waters across the Pacific. By 2004, they had roamed as far as Canada, before reaching Alaska in 2005. ➤

HUMBOLDT SQUID FACTS

THEY ARE CANNIBALS

"As soon as a squid gets hooked and others see it is caught or behaving differently, they attack," says Roger Hanlon of the Marine Biological Laboratory in Woods Hole, Massachusetts. Unai Markaida, at the Colegio de la Frontera Sur in Campeche, Mexico, looked at 533 squid and found that 26 per cent had eaten other Humboldt squid. The bigger the squid, the more frequently it ate its own kind. Females resort to cannibalism more often than males, perhaps even eating their mates.

THEY ARE MASTER MIGRATORS

Scientists have tracked adult squid migrating from Monterey Bay in California to spawning grounds off Baja California in Mexico – a distance of 600 kilometres, which they cover in just 17 days. In addition to horizontal migrations, Humboldt squid migrate vertically every night, from at least 200 metres down to the surface.

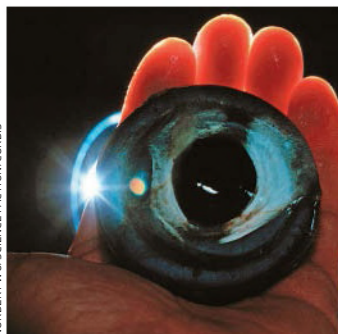
THEY HUNT IN PACKS

Gilly and Kelly Benoit-Bird at Oregon State University have seen groups of up to 40 squid swim in complex ascending spirals during night-time hunts.

THEY FLASH DIFFERENT COLOURS FROM WHITE TO A DEEP RED

One reason may be camouflage. Hannah Rosen at Stanford University says they can make muted waves of red and white scroll across their body like the undulating pattern of sunlight through the water.

They can also pulse like a strobe. According to William Gilly, also at Stanford: "There's jitter, variation and change in the frequency and timing between two squid. It is highly unlikely this isn't some kind of communication. It's a very elaborate behaviour to accomplish nothing."



NORBERT WULSCIENCE/FACTION/CORBIS



CARRIE VONDERHAAR/OCEAN FUTURE SOCIETY/GETTY

Red Devils are sometimes aggressive towards divers

One explanation for their frenetic Pacific takeover is that they are seeking prey further and further north as their usual hunting grounds become depleted. But marine biologists also have another theory.

Humboldt squid are masters at surviving in the oxygen minimum zone – vast volumes of deep water, devoid of sunlight but rich in floating microbes. The microbes break down any organic matter that drops from the surface and use up all the oxygen in the process. Unlike other large animals, Humboldt squid can spend hours at a time in these oxygen-starved regions. Recent studies have shown that they survive the low oxygen levels by drastically lowering their metabolism and slowing their pace. They are powerful swimmers capable of outmanoeuvring most fish, says Gilly, but in the oxygen-poor deep, they become far more sluggish – probably to conserve energy.

The red devils' ability to live in oxygen minimum zones could be an important factor in their recent expansion. Climate models predict that oxygen minimum zones will expand as temperatures rise, and Lothar Stramma of Kiel University in Germany has found evidence that this is already happening in places. Meanwhile, Julia Stewart-Lowndes at the University of California in Santa Barbara has examined Humboldt squid expansion and found that it parallels the expansion of the oxygen minimum zones.

Life in the deep

A turning point for Humboldt squid came in 2009, when another El Niño hit the Gulf of California, causing the squid fishery to collapse. In the aftermath, the same weather patterns that brought California its current drought also reduced upwellings of nutrient-rich deep waters in much of the Gulf, punishing the entire food chain. In response,

the squid moved deeper into the Gulf, to the Salsipuedes basin – a narrow strip of water that remained relatively rich thanks to localised, tidal upwellings. There, they performed a seemingly impossible transformation.

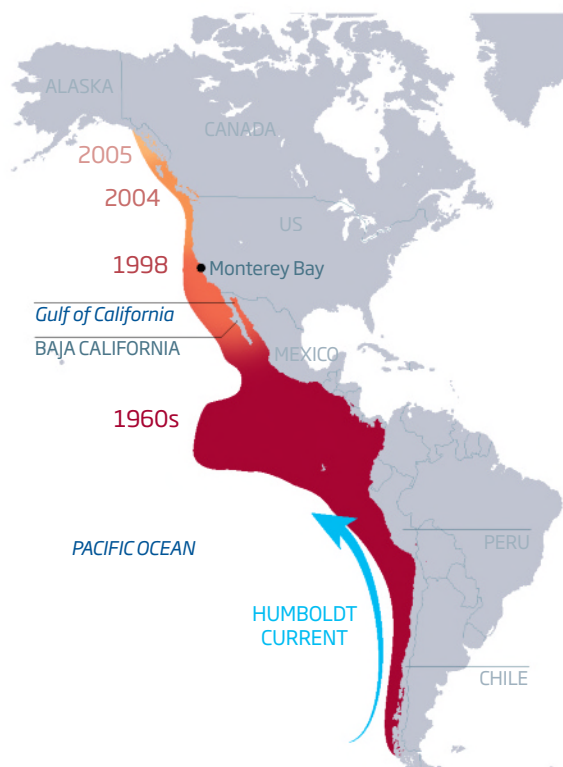
First, they shrank. Instead of catching squid with mantles more than 55 centimetres long, fishermen were now pulling in animals less than 30 centimetres long. That in itself could be explained. Humboldt squid grow with the size of their prey – smaller prey makes for smaller squid and vice versa. For instance, long-term survey cameras positioned underwater in Monterey Bay in the 1990s caught Humboldt squid switching from snacking on small lantern fish to feasts of rockfish, sole, barracuda and salmon. As they did so, their average body size got bigger.

So it's possible that the Gulf of California population simply adapted to smaller prey when the El Niño culled their usual meals. But that's not the end of it. Henk-Jan Hoving of the Helmholtz Center for Ocean Research in Kiel, Germany, was one of the first to study the transformation. He found that not only were the squid growing to smaller adult sizes, they were also reaching sexual maturity earlier – much earlier. Instead of maturing in a year and a half, spawning and dying, in the Salsipuedes basin they were reaching sexual maturity at 6 months or less. He says the finding amazed him and his colleagues. Gilly finds it equally surprising. "It's like a tiger turning into a weasel," he says.

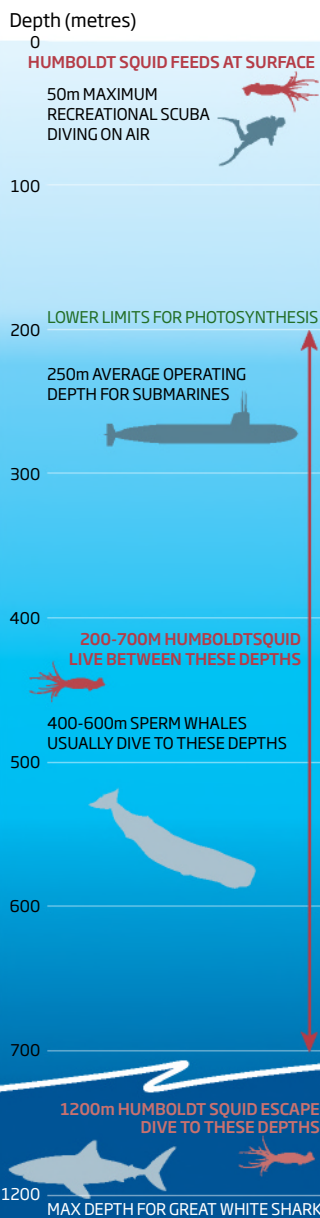
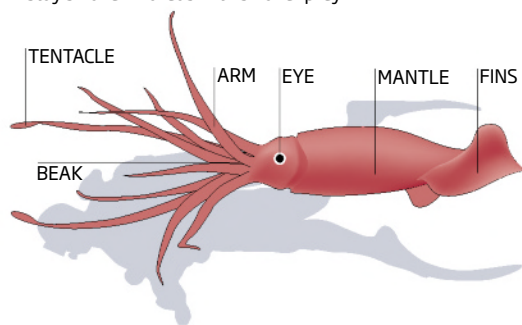
One of Hoving's theories is that the eggs and juveniles that were around during the 2009 El Niño were exposed to warmer temperatures, which altered biochemical pathways in their genes. "The environment may have an effect on gene expression during egg development, which leads to changes in growth and sexual maturity that are only visible later in the life of the animals," he says. Whether such changes

Jumbo expansion

Until a few decades ago, Humboldt squid were mostly found in the Humboldt current off the coast of South America. Now they have reached much further north



Humboldt squid can grow to be the size and weight of an adult human. However, they stay smaller in areas with smaller prey



CLIMATE ANI-MORPHS

Humboldt squid aren't the only ones changing in the face of climate change (see main text).

Soay sheep live on the island of Hirta off western Scotland. Over the past 20 years, they have been shrinking. Natural selection has so far favoured bigger sheep able to cope with tough winters, but as global warming has shortened the winters, smaller sheep are now the norm.

When the temperature climbs in the Australian outback, male **bearded dragon lizards** turn into females. Researchers worry climate change could push them toward unisex extinction. That may not come to pass, however: sex-reversed females are

laying more eggs than "normal" females.

"One could argue that dad lizards make better mums," says Clare Holleley of the University of Canberra.

In Alaska's Auke Creek, **pink salmon** have responded to earlier springs by migrating two weeks earlier than 40 years ago. This turns out to be genetically inherited, demonstrating that pink salmon may be able to evolve to stay ahead of climate change.

Polar and grizzly bears have traditionally been kept apart by ice, snow and different hibernation patterns. No more. As temperatures rise, hybrid "grolar" bears have been confirmed by DNA analysis.

are inheritable isn't known.

All this should have changed after the El Niño passed, as happened following the 1997 to 1998 event. Instead, the squid have maintained their dwarfed life-cycle.

Studies suggest that weather patterns are once more at play. Winter winds that blow into the Gulf from the US have greatly diminished during the California drought, prolonging the effects of the El Niño. Upwellings are still weak, food is still scarce and the squid are still small.

For the Humboldt squid, being small and reaching maturity earlier may be the better strategy for now. Certainly, there are advantages to gigantism – larger animals have fewer predators, for instance. Larger squid also produce more eggs, but they only do this once in their lifetime, so reaching sexual maturity earlier reduces the chances of being eaten before spawning the next generation. "That may be a suitable strategy when you're colonising new realms," says Hoving.

More change ahead?

The squid do indeed appear to be colonising. Measurements suggest that their biomass nearly doubled in the Gulf of California from 2010 to 2011. And Gilly believes we may see them return to jumbo sizes. "It may be that they need two seasonally distinct migration sites in order to grow larger body sizes," he says. Before 2009, the Gulf squid grew as large as their Peruvian cousins by migrating between a winter feeding ground on the continental side to a summer one on the peninsula. "We're watching to see if [a new winter site] develops," says Gilly.

Biologists are also mulling how an approaching El Niño, currently spreading across the Pacific, might affect the squid. "The 1997 to 1998 event is when they first started appearing off California," says Stewart-Lowndes. "But after the 2009 to 2010 event, they sort of disappeared." What will happen this time is anyone's guess.

If one thing seems certain, it's that this devil is full of surprises. To those who study the Humboldt squid, their incredible ability to survive when times are harsh by adapting at all costs is what sets them aside. It means that when an opportunity presents itself, they can bounce back and fill newly vacant ecological niches. Gilly thinks that if an extinction were to wipe out other animals higher up the food chain – like sharks, tuna or sperm whales – the Humboldt squid could be a contender to fill their shoes. "If someone wanted to design an ocean predator for the future," he says, "this would sure be it." ■

Michael Tennesen is a freelance writer based in California. His book, *The Next Species*, is published by Simon & Schuster

Healing rhythms

Is music therapy due a reprise, asks Emma Young

IN A hospital in north London, a group of adults with mental health problems improvise a song while listening to a low-pitched hum. In a consulting suite in New York City, a cancer patient gets her chemotherapy and a quartz crystal singing bowl “treatment” at the same time. At kindergarten, a child with autism is taught new words by hearing them sung. At a care home for the elderly, people with dementia are played old-time tunes to help them recover lost memories.

Across the Western world, music therapy is becoming increasingly common. Although some treatments may seem a bit New Age, the idea has an instinctive appeal to many. After all, we are a musical species – our ancestors have been healing with sound for millennia, and today many of us play music to alter our moods. But how exactly does sound affect our minds and bodies? And just how does music stand up as a treatment for medical disorders? Surprisingly, these questions are only just starting to be answered.

“Most of what we think we know about music therapy comes from anecdotes,” says neuroscientist and musician Daniel Levitin at

Things are beginning to change, though. Last October, a team at Queen’s University Belfast, UK, announced results from one of the first big randomised controlled trials to investigate the psychological effects of music therapy. The findings have yet to be published, but the research showed musical improvisation can boost self-esteem and reduce depression in children and adolescents with behavioural and emotional problems. “Now we have robust clinical evidence to show beneficial effects,” Reilly said at the time.

Sick notes

Of course it will take more than this, not least because music therapy is many things to many people. But the will is there – one stated aim of the American Music Therapy Association is to make music therapy more evidence based. “The biggest hurdle is funding,” says Levitin. Large randomised trials don’t come cheap, and grant agencies tend to view such ventures as a lower priority than curing diseases. Strong evidence that music therapy works may be slow in coming, but we are getting some fascinating insights into how it might help.

We know that music has some interesting effects on our brains. Plenty of studies show that listening to the music you like – whatever it is – stimulates the reward centres and makes you feel good. This is partly down to the release of dopamine, a signalling chemical linked to reward. Studies by Levitin and others suggest the brain’s natural opioids also play a part. Their findings might help explain why music can act as an analgesic, and support its use by some hospitals to help relieve pain after surgery.

Some types of music may have greater healing potential than others. A key factor ➤

“Slow-tempo music can reduce heart rate, blood pressure and temperature”

McGill University in Montreal, Canada. “And it’s important to remember that the plural of anecdote is not data.” Even enthusiasts like Ciara Reilly, chief executive of the Northern Ireland Music Therapy Trust, agree. “For a long time, we relied on anecdotal evidence and small-scale research findings about how well music therapy works,” she says.





BSIP/UGC VIA GETTY IMAGES



PAUL A. SALISCHIKER/MILLENNIUM IMAGES, UK

Beyond the audible

Extreme sounds can have powerful effects. Ultrasound - frequencies above 20,000 hertz - may trigger discomfort and nausea, and there is speculation that it could be, or even has been, used as a sonic weapon. But it also has potential benefits.

In 2014, William Tyler at Virginia Tech Carilion Research Institute in Roanoke and his colleagues focused ultrasound waves on the region of the cerebral cortex that processes sensory information from the hand. As a result, the volunteers' sense of touch became more sensitive. The team thinks that the stimulation alters the normal balance of inhibition and excitation of neurons within a targeted region. "We can use it to target an area of the brain as small as the size of an M&M," says Tyler.

At the opposite end of the sound spectrum, frequencies below about 20 hertz, which are too low for us to hear, can make people feel uneasy, give them chills down the spine and trigger nervous, fearful feelings. According to Richard Wiseman at the University of Hertfordshire in Hatfield, UK, such infrasound helps generate the strange feelings associated with some "haunted" buildings. It might also explain the uneasiness experienced by some animals and people before an earthquake or a storm, both of which generate infrasound. And, says Wiseman, the high level of infrasound in organ music may contribute to some intense religious experiences that have been reported in churches.

On your wavelength

While rhythm and melody have known effects in the brain (see main story), sound frequency is less well explored. Flinton Chalk wants to change that. An artist and musician, he is involved in a programme for patients at Barnet, Enfield and Haringey Mental Health Trust hospitals in London. The therapy includes exposure to 111 hertz – characteristic of a low baritone voice – a frequency that Chalk believes can alter brain activity. “It’s benign, it’s relaxing, but it can induce a mild trance-like state. It’s quite potent,” he says. Mystical claims for the power of 111 (or sometimes 110) hertz abound on the internet, but Chalk is keen to distance himself from all this. He wants researchers studying anxiety and autism to run clinical trials exploring the effects of such frequencies. When he talks to them, he points to a study led by Ian Cook at the University of California, Los Angeles.

Inspired by the discovery that a diverse group of Stone Age sacred structures had resonant frequencies centred around 110 hertz, the UCLA team wanted to explore the idea that our ancestors might have chosen or even designed these chambers to intensify the impacts of ritual chanting on the body or brain. In 2008, they published results from a pilot study in which they scanned the brains of volunteers exposed to several frequencies including 110 hertz, and found some “intriguing differences”. Unlike other frequencies, 110 hertz seemed to reduce activity

in the left frontal region, apparently quietening language centres. The finding led Chalk to wonder whether exposure to the frequency might help to ease the ruminative worry associated with anxiety, for example.

At the University of Trieste, Italy, Paolo Debertolis and his colleagues recently took the research further. They used EEG to investigate the effects of 90 to 120 hertz. Again, they found changes to brain activity – but not those observed by Cook. There were no left/right hemisphere effects, but each volunteer responded most strongly to a particular tone in the range. For some, this manifested as more activity in the frontal lobes, and they experienced ideas and thoughts similar to those associated with meditation. Others showed a shift to posterior (occipital lobe) activity, and reported “seeing” more images.

What are we to make of all this? According to neuroscientist and music expert Larry Parsons at the Centre for Cognitive Neuroscience in Bron, France, neurons transmit signals at a rate of about 1 every millisecond, a frequency of 1000 hertz – so tones around 110 hertz would be too slow to drive communication between brain cells. But neural networks – groups of neurons working together on a task – could operate at this speed, and perhaps be influenced by external sound signals, he suggests. Whether he is correct and medics can exploit the effect, only time will tell.

BSIP/UCI VIAGETTY IMAGES



appears to be rhythm. One reason is that neurons in the brainstem seem to fire synchronously with the tempo of sounds we hear. In a review of research on the neurochemistry of music, Levitin and his colleague Mona Lisa Chanda cited research showing that slow-tempo music can reduce heart rate, blood pressure, body temperature and other responses controlled by the brainstem. Such rhythm effects might help music combat stress and anxiety.

Tune your body

Another possible mechanism was reported in June at a meeting of the British Cardiovascular Society. Research by Peter Sleight at the University of Oxford indicates that slow music with a 10-second repetitive cycle calms listeners. He believes this is because it matches the length of a cycle of signals sent from the brain to the heart to regulate blood pressure. Music by Verdi, as well as the slow movements of Beethoven’s ninth symphony and the arias in Puccini’s opera *Turandot* are rich in such 10-second cycles. Further research of this type might “reduce scepticism about the real therapeutic role of music”, says Sleight.

“I look at the human body like an instrument: just as you have to tune a guitar or a piano you also have to tune the body,” says Mitchell Gaynor, an oncologist at Weill Cornell Medical College, New York City, who treats his patients with meditative chanting, as well as a host of other music and sound-related



FRANZISKA KLOSE/PLANPICTURE



Key notes: listening to music increases your pain threshold

coupled,” says Thaut. “You can witness this yourself, if you go to a concert and a rock band’s playing. Everyone taps their feet or moves to the rhythm, instinctively.” By controlling the rhythm of a piece of music, or even simply using a metronome, people can be helped to move in a more coordinated way.

Music therapy is also well established for treating speech and memory problems. When we sing a tune, the right and left hemispheres of the brain are both activated, says Thaut. When we speak, only the left hemisphere is activated. So, if a person suffers a stroke that damages certain areas in the left hemisphere, they can lose the ability to speak. “But we can sometimes reactivate speech by teaching them how to sing words,” he says. “Here, melody would be very important.” Likewise for people with dementia such as Alzheimer’s disease, where playing a favourite song can, in some cases, trigger memories.

Some of the benefits probably come from a patient’s expectations that music therapy will work, admits Thaut. Placebo effects are documented with dummy medications, he says, so when it comes to music – something that we actually like – prescribed by a doctor, placebo effects may be strong.

Others argue that music may have nothing unique to offer as a therapy. David Felten at the University of California, Irvine, suspects that it exerts much of its healing effect by reducing stress. If so, does music provide anything that another stress-buster can’t? The truth is, we don’t know. Most of the randomised controlled trials evaluating music therapy have not in fact been properly controlled, says Levitin. Often, music isn’t compared with another pleasant distractor, such as listening to an audio book, watching a comedy video or doing a crossword puzzle.

But even if stress reduction isn’t unique to music, it is still a potent force. The stress hormone cortisol inhibits the activity of immune cells called natural killer cells. So, by reducing stress and thus cutting levels of cortisol, music could help the body to fight diseases, including certain forms of cancer. “I think that’s a big part of it,” says Gaynor.

There are a lot of unknowns when it comes to music therapy, but there’s also no doubt it has some health-giving effects on our minds and bodies. Better yet, music is non-invasive, safe and cheap, and we’ve evolved to benefit from it. So maybe it’s time to turn up your favourite songs and tune up your body. ■

Emma Young is a writer based in Sheffield, UK. Her latest book is called *Sane*

therapies, along with chemotherapy. Gaynor’s ideas may not chime with most medical practitioners, but his treatments are unquestionably part of a trend. “More and more of the big medical centres are starting to use music therapy,” he says. While some people want stronger evidence that it works, Gaynor says modern medicine should be doing even more to explore its potential. “Sound and voice and music and chanting have been used in every culture on Earth for healing – up until our recent culture.”

Many proponents of music therapy cite our long evolutionary relationship with music. The oldest known instruments are bone flutes dating from up to 40,000 years ago, but our ancestors were doubtless singing and making music long before that. Evolutionary biologists believe music has been crucial in our development as a social species. In particular, sharing a musical experience with others can promote bonding, which may help explain some of music’s healing powers. Earlier this year, Levitin and his colleagues reported that playing music together, in the form of the video game *Rock Band*, substantially increases empathy between strangers, and seems to reduce levels of stress. “So much so that it alters their pain thresholds,” says Levitin.

One person who needs no convincing is Vera Brandes, director of the research programme in music and medicine at the Paracelsus Private Medical University in Salzburg, Austria. In 2009, she reported that simply

“By reducing levels of cortisol, music could help the body fight diseases”

listening to a specially compiled playlist for five weeks reduced the symptoms in people suffering from burnout – exhaustion from chronic stress. A pilot study on people with high blood pressure found music increased the amount of variability in heart rate, which is a good thing because it indicates healthy vagal tone – the vagus nerve is a crucial component of the parasympathetic nervous system, which calms you down. Poor vagal tone has also been associated with depression, which Brandes treats with music too.

Others are more cautious. Michael Thaut, director of the Center for Biomedical Research in Music at Colorado State University in Fort Collins, says we need more evidence that music therapy can help treat clinical depression and severe stress. But its effectiveness in other areas is better established, he says.

One such area is movement. Dopamine, released by the brain in response to music we find pleasurable, is critical in the regulation of movement. This may be one reason that music can help people who have problems coordinating movement, especially those with Parkinson’s disease, who don’t have enough dopamine. Another important factor is, once again, rhythm. “The connections between the auditory and motor system are very tightly

All the world's a lab

Can theatre really take on science, wonders **Stewart Pringle**

EARLY on in Anna Ziegler's *Photograph 51* – a play about Rosalind Franklin and her role in the discovery of DNA's double-helix – there is a scene in which Franklin is admired by her hated research partner Maurice Wilkins.

As Wilkins watches a ghost-like vision of Franklin cross the stage, US scientist Donald Caspar watches and compares Wilkins's confused fascination with her to the progress made by his rivals, James Watson and Francis Crick at the University of Cambridge. He says: "To Watson and Crick, the shape of something suggested the most detailed analysis of its interior workings. As though by looking at something you could determine how it came to be... how it gets through each day."

Caspar is talking both about the pair's approach to unravelling the structure of DNA and about Wilkins's struggle to understand Franklin – an incompatibility that arguably let Watson and Crick nab their Nobel.

When *Photograph 51* premieres in the UK this week, Franklin will be played by Nicole Kidman in one of this autumn's major openings. But as science takes to the big stage again, once more

its role is a strictly supporting one. The play will be the latest in a long line to use science as a metaphor, symbol or simply as an excuse to explore the human or a human. It stands in for the messy business of relationships, and it provides reassuringly precise images for the mysteries of love, memory and death.

Science in theatre is nothing new, and neither is its reduction to a kind of window-dressing. One of last year's successes, Jennifer

"This is science as an agent of perspective: thrilling, but also a little unsatisfying"

Haley's *The Nether*, was promoted as a "haunting sci-fi thriller". For all its gleaming surfaces and glitch-chic set design, however, the issues *The Nether* really cared about were privacy, online identity and moral limits.

Likewise, Lucy Prebble's 2012 hit at the UK's National Theatre, *The Effect*, examined the burgeoning relationship between two volunteers testing a "Viagra for the heart". Prebble touched on neurology, consciousness and medical responsibility, but soon

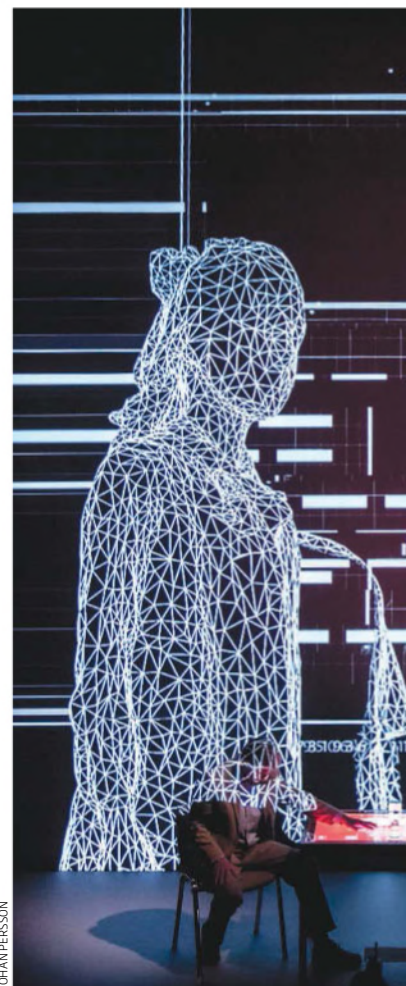
returned to her essential theme: where does love reside?

Nick Payne's time-bending love story *Constellations* used quantum multiverse theory and the habits of bees to contemplate the swerves and missed opportunities that make up our lives and our relationships.

All three of these recent hits exist at right angles to the science they describe. They use thought-experiments and imagery to stress-test their characters, placing the incidents of their lives under a microscope, perhaps, or viewing them against deep time as if relayed from a telescope thousands of light years away. This is science as an agent of perspective: thrilling but also a little unsatisfying.

Theatre is leading a cultural movement that sees the arts engaging more deeply with the sciences. The charitable Wellcome Trust, now a major funder of the performing arts, introduces theatre makers to "appropriate" scientific experts, partly so that the science we encounter on stage will be half-way accurate, but mostly so that the scientists and theatre-makers will be inspired to create works that genuinely straddle the supposed divide between the sciences and the arts.

That kind of ambition, funded well, generates plenty of strong and interesting work. Daniel Bye's latest work, *Going Viral*, which played at the Edinburgh Festival Fringe, with its story of a global epidemic of uncontrollable weeping, examines virality in all its forms. It is a true hybrid, neither story nor lecture but something new. Bye, whose work has previously tackled global capitalism and the psychology of protest, worked closely with



JOHAN PERSSON

Scientific misses: *The Nether* (above) and *The Effect* (below, left)

Mark Booth, a senior lecturer at Durham University, who checked the accuracy of Bye's digressions on epidemiology and bounced ideas around with him as the show's story developed.

Bye's show has scooped a Fringe First award. But in discussing the role funding played in its creation, and in the wider UK theatre scene over the last few years, Bye sounds a note of caution: "If people are making work they wouldn't be making otherwise, then that's a problem." It isn't the funding available from Wellcome that's at issue, so much as the scarcity of funding from elsewhere. Will the trust inadvertently deform theatre to its own image?



GERANT LEWIS/REX/SHUTTERSTOCK



Good science need not equal good theatre, and this year threw up a textbook example of truly bad theatre, Tom Stoppard's *The Hard Problem*, which opened in January at the National Theatre.

An attempt to explore consciousness, it enslaves its characters to its science, forcing them to deliver chunks of Australian philosopher David Chalmers until the play all but disintegrates under its own weight. Stoppard's characters explain thought experiments and real experiments with clarity and intelligence, but their own lives feel hollow. Stoppard has been characteristically thorough with his research, with a long list of collaborators appended to the play-text. Frankly, it shows.

There is no real need for *The*

Hard Problem to be a play. The concept has already been well outlined in books, TED talks and presentations. The play would be better without the need to bend its conversations around this. In fact, it may be a mistake to uncritically accept the benefit of staging science full stop.

Yet there is clearly enthusiasm for it. Michael Grandage is no fool, and his production of *Photograph 51* presses the same cultural button that launched Benedict Cumberbatch's cinematic portrayal of another sidelined but vital figure in the history of modern science – Alan Turing – in *The Imitation Game*.

Hollywood, meanwhile, is awash with superheroes like *Iron Man*'s Tony Stark – rock'n'roll scientists cracking unfathomable problems with a wave of their hand. Put simply: genius is in.

This year Tangram Theatre has completed a "Sciencrilogy" of scientific musical comedies with *The Element in the Room*, which explores the life of Marie Curie. The company's artistic director, Daniel Goldman, puts the public enthusiasm for science down to our love of big ideas. "In a world with so many remakes and rehashes of old movies and old stories, people are on the search for huge questions," he says. "Those naturally lead to the men and women who asked them. We want big ideas, and there's no field with bigger ideas or asking bigger questions than science."

Big questions. Big ideas. Hard problems. They are the common ground between Einstein and Shakespeare, Paracelsus and Peter Brook. But theatre and science aren't comfortable bedfellows. And a theatre district where financial pressures and box office demands draw them into unnaturally close quarters will quickly tire. ■

Stewart Pringle is a London-based writer, artistic director and theatre critic. *Photograph 51* opens at London's Noel Coward Theatre on 5 September (see our review at newscientist.com)

Pondering the fall

Simon Ings leafs through autumn books

CHANGE is in the air; what better time to consider humanity's end – and its possible salvation?

Any artificial intelligence that makes better versions of itself will rapidly outcompete humans – the so-called "technological singularity". But will it "want" to? Can AI "want" anything? *The Technological Singularity* (MIT Press, \$15.95/£10.95) by Murray Shanahan runs through various scenarios, not all apocalyptic.

Back in the present, Jim Rogers's *Lighting the World: Transforming our energy future by bringing electricity to everyone* (St. Martin's Press, \$26.99) points out that 1.2 billion people still don't have electricity. But bringing power to the poorest should be easy: there is no old infrastructure in the way. And solving the energy problems of sub-Saharan Africa will provide a blueprint for weaning the developed world off oil. Rogers ran Duke Energy, the largest electric power company in the US, for 7 years; now the elite take note of him.

In poorer countries, charging your phone can involve walking miles



Big science and big engineering have adapted well to today's asymmetric conflicts – too well for Andrew Cockburn's taste. *Kill Chain: Drones and the rise of high-tech assassins* (Verso, £20/Henry Holt, \$28) lays bare the political and moral consequences of leveraging technology to address the amorphous dreads of intelligence-starved diplomats. Pre-emption as a strategy comes under fire (as it were), as does the idea of fighting wars with remote cameras that are, according to one veteran, "no better than looking at Google Earth through a straw".

The more virtual our lives become, the more we take craft seriously. Colin McGinn's *Prehension: The hand and the emergence of humanity* (MIT Press, \$24.95/£17.95) provides the scientific argument for craft, linking various human tics, habits and anxieties to our ability to manipulate the physical world. Singularity enthusiasts take note: human intelligence (the only one we know much about) has had hundreds of thousands of years to become very odd indeed. Copying it will be hard. ■

A breathtaking adventure

Rowan Hooper devours a wildly ambitious guide to all of life

Evolution: The whole story, edited by Steve Parker, Thames & Hudson, £19.95

FANCY a bit of time travel from your armchair? *Evolution: The whole story* is just the job, condensing millions of years of Earth's history into a highly accessible work.

Opening it at random, for example, I found myself in the early Jurassic, 190 million years ago. There stood *Dilophosaurus*, a feisty-looking theropod dinosaur shown in a colourful, dynamic pose. I skipped forward, again at random, and found myself in 2015, looking at the California condor, a magnificent – and critically endangered – bird.

Back in time again, and I ended up in the Cretaceous with *Beipiaosaurus*, a bizarre, monstrous-looking beast that I learned is the ancestor of predatory raptor dinosaurs and birds. Time to turn the dial way back, to 500 million years ago in the middle Cambrian, where I confronted the infamous *Hallucigenia*, a spiky, worm-like species that defied classification for years.

This is such an attractive and friendly book – reading it is like losing a weekend to a box set of *Doctor Who* – that it would be easy to glide over its real accomplishment. I cannot think of another book that attempts to catalogue the entire expanse of life and succeeds in such a remarkably palatable way. It manages to delve formidably deep, all the way back to Earth's formation 4.5 billion years ago, then forward to the

origin of life, the first fossils and the explosion of new organisms in the early Cambrian. Mammals and apes are given their proper due without taking over the book.

Each organism is covered across two pages that are full of images, graphics and amazing facts, so the reader is not overwhelmed by a mass of text. The approach breathes life into everything, including “boring” stuff (that is, non-dinosaur stuff).

I even warmed to the ginkgo tree, an extraordinary plant that has been around for 300 million years – in recent times largely thanks to the husbandry of Buddhist monks. If the immensity of geological time has started to wash over you, this will wake you up: the ginkgo has sperm with tails that allow them to move.

Evolution, compiled by a panel

of scientists and science writers, was edited by zoologist and prolific author Steve Parker, who sticks strictly to established facts and consensus interpretations, as is right in such a project. For example, at the end, in a chapter on human influence, the authors define the current sixth mass extinction as the Holocene extinction, using the classical

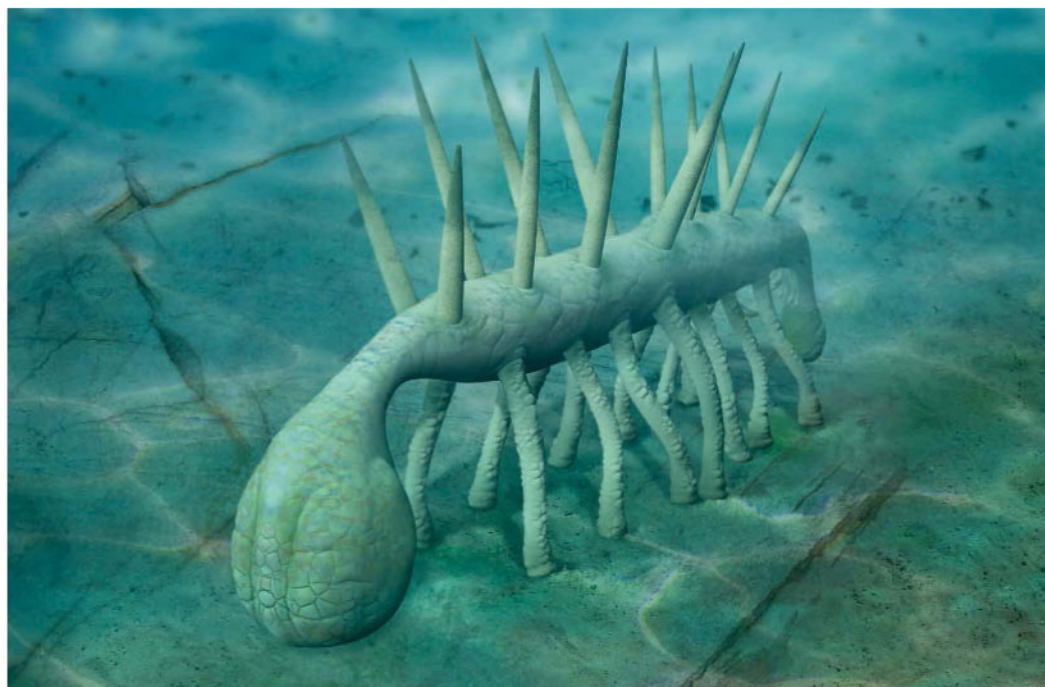
“The approach even breathes life into ‘boring’ stuff – that is, non-dinosaur stuff”

name for the current epoch, rather than Anthropocene extinction, a widely used although still unofficial term.

This strait-laced style and the cover, a serviceable but dull chimpanzee portrait of the sort that readers

will have seen a thousand times before, belies the book's bright, breezy and modern approach. The sheer ambition of the book – and the strong and immediate sense it conveys of life's diversity – is impressive, although I did fleetingly fear that I had been landed with a work of creationist madness. The name of Alice Roberts on the cover (as the author of the book's foreword) reassured me: Roberts is a writer, broadcaster and clinical anatomist. But still I wondered whether Thames & Hudson, a publisher of “whole stories”, including those of photography, architecture, art and cinema, was wise to attempt to account for the entirety of life on Earth.

My worries were misplaced. This guide is definitely one for the Tardis library. ■



For years, the surreal-looking *Hallucigenia* defied classification



The future belongs to the fast.



IT strategy is now business strategy.

In a changing landscape, every company faces the challenge of quickly moving from what they are now to what they need to become. This has made IT solutions that can accelerate change the single most important strategic weapon for business. HP believes that when people, technology and ideas all come together, business can move further, faster. To find out more, visit us at hp.com/uk/furtherfaster.

Harvard University
Faculty of Arts and Sciences, Cambridge, MA
Department of Chemistry & Chemical Biology
TENURE-TRACK PROFESSOR



Position Description: The Department of Chemistry & Chemical Biology seeks to appoint a tenure-track assistant professor in the open field of chemistry and chemical biology. The appointment is expected to begin on July 1, 2016. The tenure-track professor will be responsible for teaching at the undergraduate and graduate levels.

Basic Qualifications: Doctorate or terminal degree in chemistry or related discipline required by the time the appointment begins.

Additional Qualifications: Demonstrated excellence in teaching is desired.

Special Instructions: Please submit the following materials through the ARIAS portal (<http://academicpositions.harvard.edu/postings/6320>). Applications must be submitted no later than October 15, 2015.

1. Cover letter
2. Curriculum Vitae
3. Teaching statement (describing teaching approach and philosophy)
4. Outline of future research plans
5. Names and contact information of 3-5 references (three letters of recommendation are required, and the application is complete only when all three letters have been submitted)
6. List of publications

Harvard is an equal opportunity employer and all qualified applicants will receive consideration for employment without regard to race, color, religion, sex, sexual orientation, gender identity, national origin, disability status, protected veteran status, or any other characteristic protected by law.

Contact Information: Helen Schwickrath, Search Administrator, Department of Chemistry & Chemical Biology, Faculty of Arts and Sciences, Harvard University, 12 Oxford St., Cambridge, MA 02138. Phone: (617) 495-8190.

Contact Email: Helen@chemistry.harvard.edu



Faculty Positions in Biochemistry and Molecular Biophysics

The Department of Biochemistry and Molecular Biophysics at Washington University School of Medicine invites applications for several tenured/tenure-track faculty positions at the level of Assistant/Associate/Full Professor. Successful candidates will have established a strong record of research. Applicants seeking tenured positions must have a strong record of external funding.

Outstanding individuals working in any area of biochemistry and molecular biophysics are encouraged to apply. The candidate's research should be aimed at addressing fundamental questions related to molecular mechanisms of biological or biomedical relevance. Current research in the department spans a wide range of topics including computational biology, membrane proteins, molecular motors, nucleic acid/protein interactions, protein structure, enzymology and signal transduction. Additional information about the department is available at <http://www.biochem.wustl.edu>. Washington University has a highly interactive research environment with vigorous interdisciplinary graduate and medical scientist training programs.

Applicants should email their curriculum vitae, brief description of their research interests, and contact information of three individuals to the Search Committee at bmbsearch@biochem.wustl.edu. The committee will request letters from these individuals as necessary.

Completed applications will be reviewed on a rolling basis, starting immediately. For full consideration, applications should be received by December 1, 2015.

EOE/Minorities/Vets/Disabilities. The School of Medicine at Washington University is committed to finding solutions to global health problems, including ones that affect minority and disadvantaged populations.



ASSISTANT PROFESSOR in Complex Systems

The Center for the Study of Complex Systems (CSCS) at the University of Michigan invites applications for a tenure-track position of Assistant Professor of Complex Systems. Candidates at a more senior-level will also be considered. The appointment will begin **September 1, 2016**. This is a University-year appointment. Information about the Center can be found here: <http://www.lsa.umich.edu/cscs>.

Required Qualifications

Candidates must have a demonstrated research agenda focusing on complex systems. This may involve theoretical or applied research on complexity, including (but not limited to) mathematical and computational models in areas such as networks, computation, emergence, large events and robustness or applications where complexity lies at the core such as quantitative modeling of social systems, soft condensed matter physics, evolutionary or ecological dynamics, epidemiology and disease transmission, artificial life, neuroscience, and cognition. Preference will be given to candidates with a track record of working across disciplines.

How to Apply

All application materials must be uploaded onto this website:

<https://complexsystems-lsa.applicantstack.com/x/apply/a2guio5y9cxr>

The position is based in CSCS but will be a joint appointment with another department. In the cover letter, candidates should identify one or more partner departments at the University of Michigan suitable for such a joint appointment. Applicants must submit: a current CV, statement of current and future research plans, a statement of teaching philosophy and experience, evidence of teaching excellence (if any) and one writing sample. At least three letters of recommendation are required and must be uploaded onto the same website. Applications will be reviewed starting **October 1, 2015**. Applications will be accepted until the position is filled.

Women and minority candidates are encouraged to apply. The University of Michigan is an equal opportunity/affirmative action employer and is supportive of the needs of dual career couples.



THE UNIVERSITY
of
WISCONSIN
MADISON

MANAGING DIRECTOR Center for Sustainable Nanotechnology PVL 83199

The Department of Chemistry of the University of Wisconsin-Madison is recruiting for a Managing Director in the Center for Sustainable Nanotechnology (CSN.) The Director works with the Center Director and the CSN Executive Committee and is responsible for actively directing and coordinating scientific research and additional integrative activities at multiple institutions to achieve the center's goals. A Ph.D. in Chemistry or related field experience is required. This is a full-time position with an anticipated beginning date of **October 1, 2015**. There will be a minimum twelve-month evaluation period.

Specific duties of the Director may include: Overseeing general operation of the center; establishing and implementing center-wide policies and procedures that will maximize the effectiveness of the center's scientific objectives and associated integrative activities; oversee center-wide finances (including multiple sub-contracts) and develop financial plans for the center; ensure that Center programs and activities are compliant with federal/state regulations; interface directly with federal agency personnel to meet reporting requirements and to communicate the center's scientific progress and objectives. This will include identifying high-impact scientific results and translating into language appropriate for program managers and policymakers.

For additional information, please go to:

http://www.ohr.wisc.edu/Weblisting/External/PVLSummary.aspx?pv_num=83199

Additional information on the Center for Sustainable Nanotechnology is available at <http://susnano.chem.wisc.edu>

Please submit a letter of interest, curriculum vita and 3 references referring to PVL 83199 to **Dennis Reece at the Department of Chemistry, University of Wisconsin-Madison, 1101 University Ave., Madison, Wisconsin 53706-1322.**

To guarantee full consideration, all materials must be received by **September 15, 2015**.

The University of Wisconsin is an equal opportunity and affirmative action employer; applications from qualified women and minority candidates are encouraged. Unless confidentiality is requested in writing, information regarding the identity of the applicant must be released on request and there are deadlines for disclosure. Finalists cannot be guaranteed confidentiality. A background check may be required prior to employment



NASA

Postdoctoral Program

administered by Oak Ridge Associated Universities



The NASA Postdoctoral Program (NPP) supports NASA's goal to expand scientific understanding of Earth and the universe in which we live.



The NASA Postdoctoral Program offers U.S. and international scientists the opportunity to advance their research while contributing to NASA's scientific goals. The NPP supports fundamental science; explores the undiscovered; promotes intellectual growth; and encourages scientific connections.

Details

- Annual stipends start at \$53,500, with supplements for high cost-of-living areas and certain degree fields
- Annual travel budget of \$8,000
- Relocation allowance
- Financial supplement for health insurance purchased through the program
- Appointments renewable for up to three years
- Approximately 90 Fellowships awarded annually

Application Deadlines

Three each year - March 1, July 1, and November 1

Apply at <http://nasa.orau.org/postdoc>

Director, Division of Extramural Activities National Eye Institute



The National Eye Institute (NEI), a component of the National Institutes of Health (NIH) and the Department of Health and Human Services (DHHS), conducts and supports research, training, health information dissemination, and other programs with respect to blinding eye diseases, visual disorders, mechanisms of visual function, preservation of sight, and the special health problems and requirements of the blind.

Are you an experienced Scientific Administrator in search of an exciting career opportunity? We may be the right place for you. The NEI at the NIH is seeking an exceptional Scientific Administrator to serve as the Director, Division of Extramural Activities (DEA). The Director, DEA, reports to the Director, NEI and serves as the principal advisor on research administration policies including peer review, grants management and administrative management of the Division. The incumbent oversees several distinct but related functions involving the extramural operations and has full managerial and executive responsibility for the following activities: Providing leadership and advice on extramural research grant, contract, and training program operations and policies within NEI; Providing oversight of grants management activities and implementation of grants policies; Providing guidance at the interface of grants management and the NEI Budget Office; Providing oversight and direction for the peer review of research applications, training applications and contract proposals. The incumbent represents NEI on extramural research administration and policy committees both within and external to NIH and HHS; Provides executive and managerial oversight of policy development for extramural research grant and contract review and management procedures; Provides overall management of the operations of the National Advisory Eye Council (NAEC) and serves as its executive secretariat and managing the resources for the DEA, including financial and personnel needs.

The Director, DEA will have responsibility for the development, implementation and dissemination of extramural review and grants management policies and procedures both internal and external to the NEI. The incumbent serves as an authoritative source on NEI extramural research peer review regulations, and grants management policies, and maintains awareness of new developments in research administration through interactions at professional conferences.

QUALIFICATIONS REQUIRED: Candidates must have an M.D., Ph.D., or equivalent degree in a field relevant to the position and substantial leadership experience in managing a federally-funded extramural science program. This position will be filled under a Title 42(f) excepted service appointment.

SALARY/BENEFITS: The salary for this position will be commensurate with qualifications and professional experience. A recruitment or relocation bonus may be available, and relocation expenses may be paid. A full package of federal Civil Service benefits is available, including: retirement, health and life insurance, long term care insurance, leave, and a Thrift Savings Plan (401K equivalent).

HOW TO APPLY: Submit a current curriculum vitae, bibliography, and full contact details for three references. In addition, applicants are asked to prepare two statements: a vision statement and a statement that addresses the specific qualification requirements (please limit both statements to two pages each). Send application package to Yireiza Williams at ywilliams@nei.nih.gov by September 30.

NEI will begin accepting applications from August 25th through September 30th and plans to have the position open for at least 30 days, but will not close the applicant process until a candidate has been selected.

Information about NEI can be found at **NEI.NIH.GOV**

You may contact Yireiza Williams with questions and for more information about this vacancy at ywilliams@nei.nih.gov or on (301) 451-1936.

HHS, NIH and NEI are Equal Opportunity Employers



National Eye Institute (NEI)
Research Today...Vision Tomorrow

Director, Division of Extramural Science National Eye Institute



The National Eye Institute (NEI), a component of the National Institutes of Health (NIH) and the Department of Health and Human Services (DHHS), conducts and supports research, training, health information dissemination, and other programs with respect to blinding eye diseases, visual disorders, mechanisms of visual function, preservation of sight, and the special health problems and requirements of the blind.

Are you an experienced Scientific Researcher or Scientific Administrator in search of an exciting career opportunity? We may be the right place for you. The NEI at the NIH is seeking an exceptional Scientific Administrator to serve as the Director, Division of Extramural Science (DES). The incumbent plans and directs programs of research grants, cooperative agreements, individual and institutional research training awards, and research and development contract support for basic and applied clinical research and training as it relates to blinding eye diseases, visual disorders, mechanisms of visual function, preservation of sight, and the special health problems and needs of individuals who are partially-sighted or blind. The incumbent has responsibility for directing and managing multiple extramural scientific program initiatives and functions, managing the domestic and international extramural funding activities of NEI and providing policy direction. The incumbent advises the Director, NEI, regarding basic vision research activities, and coordinates with other NEI, NIH and DHHS organizations and the extramural community to accomplish Institute objectives. Additionally, the incumbent provides executive and managerial leadership in setting extramural scientific priorities of the Institute, making broad and significant decisions on scientific programs, developing Institute-wide policies and procedures, and determining resource allocation issues involving a major component of the Institute and a significant portion of NEI funding. Through his/her expertise and experience, the incumbent must be able to promote, manage, and oversee extramural research activities of national and international significance.

The incumbent serves as the principal advisor and liaison representing the DES and NEI on NIH work groups and committees pertaining to extramural science programs and activities and represents the Institute in interactions with the extramural community and at national and international conferences and seminars.

QUALIFICATIONS REQUIRED: Candidates must have an M.D., Ph.D., or equivalent degree in a field relevant to the position and substantial leadership experience in managing a federally-funded extramural science program. This position will be filled under a Title 42(f) excepted service appointment.

SALARY/BENEFITS: The salary for this position will be commensurate with qualifications and professional experience. A recruitment or relocation bonus may be available, and relocation expenses may be paid. A full package of federal Civil Service benefits is available, including: retirement, health and life insurance, long term care insurance, leave, and a Thrift Savings Plan (401K equivalent).

HOW TO APPLY: Submit a current curriculum vitae, bibliography, and full contact details for three references. In addition, applicants are asked to prepare a statement that addresses the specific qualification requirements (please limit the statement to no more than two pages). Send application package to **Yireiza Williams at ywilliams@nei.nih.gov** by September 30.

Information about NEI can be found at **NEI.NIH.GOV**

You may contact Yireiza Williams with questions and for more information about this vacancy at **ywilliams@nei.nih.gov** or on (301) 451-1936.

HHS, NIH and NEI are Equal Opportunity Employers



National Eye Institute (NEI)
Research Today... Vision Tomorrow



Call for Applications Chair,

Department of Medical Biophysics

The Schulich School of Medicine & Dentistry, at Western University, is inviting applications for the position of Chair in the Department of Medical Biophysics.

As Canada's first Department of Biophysics, the Department has grown to become one of Canada's leading centres for medical biophysics research with approximately 20 primary faculty members and over 70 actively collaborating cross appointed faculty leading internationally recognized research programs in medical imaging, microcirculation, computational modelling, biomechanics, and cancer. The department is the academic home to both undergraduate and graduate programs, including CAMPEP accreditation. It draws on a rich city-wide infrastructure incorporating two research Institutes, three hospitals, and five University Faculties. Research programs benefit from close collaborations between clinical and basic science faculty, with unique training programs in diverse fields.

The successful candidate should have a demonstrated track record of leadership and research and teaching excellence with a proven reputation for effective interpersonal and administrative skills. The new Chair will facilitate collaboration and be expected to support the research, educational and interdisciplinary initiatives of the Department. The successful candidate will build on the strength and forward momentum of the Department's graduate and undergraduate programs and promote the development of new initiatives in research, scholarship and education. He or she must have a PhD, MD, DDS or equivalent, and will receive a tenured academic appointment at the level of Associate or full Professor. Candidates with a research program complementing existing research strengths are particularly encouraged to apply. The position of Chair is for a five-year term, renewable.

Western University is located in London, Ontario, with a metropolitan census of 530,000. As Canada's 11th largest city, London boasts an extensive educational and health care community. With full time enrollment of 32,000, Western graduates students from a range of academic and professional programs. Further information about the Schulich School of Medicine & Dentistry and Western University can be found at www.schulich.uwo.ca, and <http://www.uwo.ca>. Western's Recruitment & Retention Office is available to assist in the transition of successful applications and their families. Details about the Department of Medical Biophysics can be found at <http://www.schulich.uwo.ca/biophysics/>.

Interested candidates should submit a CV outlining their research, teaching, and administrative experience and interests, including future directions, together with the names and addresses of three referees to:

Dr. Michael Strong, Dean
Schulich School of Medicine & Dentistry
Room 3701A, Clinical Skills Building
Western University
London, Ontario N6A 5C1
FAX: (519) 850-2357
selection.committee@schulich.uwo.ca

Please ensure that the form available at <http://www.uwo.ca/facultyrelations/faculty/Application-FullTime-Faculty-Position-Form.pdf> is completed and included in your application submission.

**Applications will be accepted until the position is filled.
Review of applicants will begin after September 30, 2015.**

Positions are subject to budget approval. Applicants should have fluent written and oral communication skills in English. All qualified candidates are encouraged to apply; however, Canadians and permanent residents will be given priority. Western University is committed to employment equity and diversity in the workplace and welcomes applications from all qualified individuals, including women and men, members of visible minorities, aboriginal persons, persons with disabilities, and persons of any sexual orientation or gender identity.

Berkeley

Department of Chemistry
UNIVERSITY OF CALIFORNIA Faculty Position in Chemistry

The Department of Chemistry at the University of California, Berkeley invites applications for one tenured faculty position at the associate/full professor level with an expected start date of July 1, 2016 in the broadly defined field of experimental physical chemistry. The basic qualification for this position is a Ph.D. or equivalent degree in Chemistry or a related field at the time of application.

All applicants should submit their most recently updated curriculum vitae, a three to five-page statement of future research plans and a statement of teaching. Additionally, please provide contact information for three to five references. We will only contact your referees if you are a finalist for the position, and we will seek your permission before doing so. A cover letter is optional. Applications should be submitted electronically through our web-based system at: <https://aprecruit.berkeley.edu/apply/JPF00804>.

All recommendation letters will be treated as confidential per University of California policy and California state law. Please refer potential referees, including when letters are provided via a third party (i.e., dossier service or career center), to the UC statement on confidentiality (<http://apo.berkeley.edu/evaltr.html>) prior to submitting their letters.

The deadline to apply for this position is November 2, 2015. Please direct questions to Lauren Nakashima (lnakashima@berkeley.edu).

The University of California is an Equal Opportunity/Affirmative Action Employer. All qualified applicants will receive consideration for employment without regard to race, color, religion, sex, national origin, disability, age or protected veteran status. For the complete University of California nondiscrimination and affirmative action policy see: <http://policy.ucop.edu/doc/4000376/NondiscrimAffirmAct>.

UC Berkeley is committed to diversity in all aspects of our mission and to addressing the family needs of faculty, including dual career couples and single parents. The Department of Chemistry is interested in candidates who will contribute to diversity and equal opportunity in higher education through their teaching, research, and service.

UAB SCHOOL OF MEDICINE

Knowledge that will change your world

The University of Alabama at Birmingham

DEPARTMENT OF PATHOLOGY

Assistant Professor in General Surgical Pathology with Hematopathology Expertise

The Division of Anatomic Pathology, Department of Pathology at the University of Alabama at Birmingham is seeking a pathologist with Board Certification for the position of Assistant Professor, rank of tenure earning. Applicants must have completed a formal fellowship in either Surgical Pathology or Hematopathology with both clinical and research expertise. Candidates must have special expertise in lymph node pathology, bone marrow interpretation and experience in flow cytometry. Candidates will be expected to take part in ongoing collaborative efforts by a multidisciplinary team of well-established investigators, aimed at evaluating hemopoietic malignancies. Candidates must have an Alabama Medical License and be prepared to handle clinical responsibilities in a large general surgical pathology practice and hematopathology consult service.

Interested candidates should submit a cover letter that includes research interest/experience, curriculum vitae, and the names of three references to the attention of Gene P. Siegal, M.D., Ph.D., Robert W. Mowry Endowed Professor of Pathology, Director, Division of Anatomic Pathology, Department of Pathology, University of Alabama at Birmingham, path-aprecruits@mail.ad.uab.edu. All applications will be accepted until position is filled.

A pre-employment background investigation is performed on candidates selected for employment. In addition, physicians and other clinical faculty candidates who will be employed by the University of Alabama Health Services Foundation (UAHSF) or other UAB Medicine entities must successfully complete a pre-employment drug and nicotine screen to be hired.

UAB is an Equal Opportunity/Affirmative Action Employer committed to fostering a diverse, equitable and family-friendly environment in which all faculty and staff can excel and achieve work/life balance irrespective of race, national origin, age, genetic or family medical history, gender, faith, gender identity and expression as well as sexual orientation. UAB also encourages applications from individuals with disabilities and veterans.



The Broad Institute brings together a diverse group of individuals from across its partner institutions - undergraduate and graduate students, postdoctoral fellows, professional scientists, administrative professionals, and academic faculty. The culture and environment at the Broad is designed to encourage creativity and to engage all participants, regardless of role or seniority, in the mission of the Institute. Within this setting, researchers are empowered - both

intellectually and technically - to confront even the most difficult biomedical challenges. The Institute's organization is unique among biomedical research institutions. It encompasses three types of organizational units: core member laboratories, programs and platforms. Scientists within these units work closely together - and with other collaborators around the world - to tackle critical problems in human biology and disease.



The Broad Institute is essentially an "experiment" in a new way of doing science, empowering this generation of researchers to:

- Act nimbly. Encouraging creativity often means moving quickly, and taking risks on new approaches and structures that often defy conventional wisdom.
- Work boldly. Meeting the biomedical challenges of this generation requires the capacity to mount projects at any scale - from a single individual to teams of hundreds of scientists.
- Share openly. Seizing scientific opportunities requires creating methods, tools and massive data sets - and making them available to the entire scientific community to rapidly accelerate biomedical advancement.
- Reach globally. Biomedicine should address the medical challenges of the entire world, not just advanced economies, and include scientists in developing countries as equal partners whose knowledge and experience are critical to driving progress.

Ryan W. Lavoie, JD Associate Director: Talent Acquisition
 The Broad Institute of MIT and Harvard
 75 Ames Street, Cambridge, MA 02142
 E: rlavoie@broadinstitute.org
 O: 617.714.8558 M: 603.583.1057



Knowledge that will change your world

The University of Alabama at Birmingham

BIOCHEMICAL GENETICIST

Department of Genetics

The UAB Department of Genetics seeks applicants for a faculty position in the field of biochemical genetics. The Department of Genetics has an established biochemical genetics program consisting of clinical diagnostic and laboratories, and a clinical consultation service. Faculty rank will be Assistant or Associate Professor and may be either tenure or non-tenure earning. UAB faculty appointment and compensation are commensurate with qualifications and experience. Qualified candidates will have M.D. and/or Ph.D. credentials, and be board certified in Clinical Biochemical Genetics or Medical Biochemical Genetics.

This individual will be Director of the Biochemical Genetics Laboratory, and will also be responsible for teaching, research and/or clinical pursuits. Prior experience should include managing and interpreting biochemical lab results including standard biochemical testing and lysosomal disease screening and testing. Applicants with research interests will have demonstrated ability to conduct significant independent research, and a successful track record of grant funding.

UAB is an Equal Opportunity/Affirmative Action Employer committed to fostering a diverse, equitable and family-friendly environment in which all faculty and staff can excel and achieve work/life balance irrespective of race, national origin, age, genetic or family medical history, gender, faith, gender identity and expression as well as sexual orientation. UAB also encourages applications from individuals with disabilities and veterans.

A pre-employment background investigation is performed on candidates selected for employment.

The University of Alabama at Birmingham offers an excellent benefits package including medical/dental insurance and dependent tuition. Interested applicants please send curriculum vitae including references, and a description of your teaching, clinical or research portfolio to:

Bruce R. Korf, M.D., Ph.D.
 Professor and Chairman
 c/o Dee Blakely-Stoudermire
 UAB Department of Genetics
 720 20th Street South, KAUL 230
 Birmingham, AL 35294-0024
dblakely@uab.edu



THE UNIVERSITY OF
CHICAGO

Assistant Professor of Chemistry

The Department of Chemistry at The University of Chicago invites applications from outstanding individuals for the position of Assistant Professor of Chemistry. This search is in the areas broadly defined as inorganic, organic and physical chemistry. Applicants must apply online to the University of Chicago Academic Career website.

Inorganic chemists apply to <http://tinyurl.com/nq59kgr>, Organic <http://tinyurl.com/oxvy7n8>, and Physical <http://tinyurl.com/py98uyk>.

Please apply to one search only. Applicants must upload a cover letter, a curriculum vitae with a list of publications, a succinct outline of research plans and a one page teaching statement. In addition, three reference letters are required. At the time of hire the successful candidate must have a Ph.D. in Chemistry or a related field. Joint appointments with other departments are possible. Review of applications will continue until all positions are filled.

Referral letter submission information will be provided during the application process.

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EDITOR'S PICK



I speak, therefore I am?

From Anthony Castaldo

The explanation provided by Peter Halligan and David Oakley for consciousness – that it emerged as a side effect of communication – appears to depend on having language to convey useful information (15 August, p 26).

It seems clear to me that animals are conscious, with or without language. I also fail to see how language develops without consciousness.

I believe it is more likely that consciousness is an emergent, scalable phenomenon, developing when the brain has so many specialised subconscious systems that they survive better with central coordination. This central system would be adaptive when rudimentary and become more adaptive as it grew stronger – and that is the supervisory clearing house we call consciousness.

The subsystems would still retain their ability to make independent decisions; the purpose of consciousness may be to coordinate, influence or inhibit such systems by providing new inputs.

For example, my dog will search for me so that I can let him out to urinate, instead of just giving in to his subsystem insisting he do it immediately.

San Antonio, Texas, US

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Not all women are equally fertile

From Ben Haller

Your “fertility calculator” article, which examines how a woman’s chance of having a particular number of children changes with age, gives a misleading view (1 August, p 6). It mentions in passing that the calculation “won’t apply to every woman on an individual basis as there is a lot of variation”, but then ignores that essential caveat.

Roughly half of women have high fertility, a further quarter have good fertility, while the remaining 25 per cent have trouble conceiving. The ages at which these women should start having children and the extent to which IVF can help them vary immensely. Averaging together people with such different experiences gives a result that cannot serve as a useful indicator.

A far better measure would be fertility testing for young women, which could tell them whether they are in the low-fertility category.

Ithaca, New York, US

Opening up a can of earworms

From Ed Hannah

Sam Wong’s article “Can’t get that song out of your head?” states that “Earworms are spontaneous thoughts” (25 July, p 10).

As one who has made a pastime of identifying earworm triggers, I’m able to report that they are often traceable to an external stimulus, and cases where I was unable to identify the source may just be a reflection of incomplete detective work.

It is interesting that the trigger need not be actual music. For example, on one occasion I realised that prior to hearing a symphony by Georges Bizet, I had seen the

name “Bizet” on a magazine cover.

Identifying the trigger isn’t always so straightforward, because the mental sequence leading to the earworm may be longer or not as direct. Further, one earworm can easily morph into another, thereby confusing the trail.

I conclude that if there are spontaneous earworms, they are outnumbered by those initiated by an external stimulus.

Armidale, New South Wales, Australia

From Georg Pedersen

Whatever a spontaneous thought is, it is hard to imagine a less spontaneous thought than an earworm – a bit of music that repeats itself endlessly after entering the brain by listening.

A far more useful concept would be seeing the obvious similarity between earworms and normal thoughts, which very frequently have an obsessive, repetitive quality.

Sydney, Australia

A universe quite by chance

From Liam O’Keeffe

I enjoyed your feature exploring discoveries that would change what it means to be human (8 August, p 28), and would like to suggest my own.

What if the fabric of the universe turns out to be random? It does seem that the more we delve into it, the more complex it becomes. To begin with, we explained the universe with Newton’s relatively simple laws of motion, which were superseded by general relativity and quantum mechanics.

Now it looks as though string theory may explain everything – but how many dimensions will we need? Will it be 10? Or 26? Or perhaps we will eventually need an infinite number.

Abinger Hammer, Surrey, UK

What are little asteroids made of?

From William Robinson

Under the title “Space bling” you mention that asteroid 2011 UW-158 “is thought to have a core made of platinum” (25 July, p 5).

This seems unlikely to me. I have no reason to doubt that some asteroids are rich in precious metals, including platinum, but the term is relative. Here on Earth, in the platinum mines of South Africa, processing around 10 tonnes of rock yields less than 30 grams of pure platinum.

Looking on the bright side, mining these asteroids could give a kick-start to our moribund space programme. Scientific knowledge and national prestige have failed to get us out of Earth orbit for the last 43 years.

Slough, Berkshire, UK

The editor writes:

■ Planetary Resources describes “X-type” asteroids they hope to mine as “composed of primarily metal. Some... large asteroids were pulverised in massive collisions early in the solar system’s history leaving only the tough metallic cores.”

Planet killers are a daily occurrence

From Michael Paine

It is interesting to read about possible asteroids in other solar systems (12 August, p 15). I wonder if those asteroids hit rocky planets as often as such bodies hit Earth, say every 100 million years for an impact the size of Chicxulub, thought to have wiped out the dinosaurs. With some 30 billion rocky planets in our galaxy, that would mean one giant impact every day. A sobering thought for the chances of advanced life.

Beacon Hill, New South Wales, Australia

Chad Myers says a universal influenza vaccine faces big hurdles (29 August, p 7).

A nose for thyroid problems

From Bryn Glover

I’d like to contribute a small anecdote to the correspondence on sniffing out illnesses (Letters, 18 July).

In the early 1960s, one of my jobs at Leeds Infirmary, UK, was administering tiny doses of radioactive iodine to people with a possible malfunction of their thyroid glands. Hyperthyroidism is often quite easily spotted because it causes bulging eyes and general hyperactivity, but I gradually became aware that I could detect a faint whiff from those with the condition, which I described as a cross between the ketotic smell of diabetes and the aroma of burnt carrots.

The consultant endocrinologist for whom I worked could not detect any odour. We carried out a short trial that was as rigorous as we could make it given the circumstances and the relatively small numbers involved.

I forget the actual numbers – it

was over 50 years ago – but my success rate in identifying thyrotoxicosis was significantly better than random. The trial was not published, although I believe a short letter appeared in an appropriate journal.

Kirkby Malzeard, North Yorkshire, UK

Should we hibernate off civil time?

From Eric Kvaalen

Richard Keyworth asks whether we could redefine the second and so reduce the discrepancy between atomic time and civil time (Letters, 15 August).

We could, but we would need to do so repeatedly. The atomic second corresponds to what was appropriate in the late 19th century – namely 86,400 seconds per day – and now it’s a bit too short because the day has got longer. If we were to redefine it, we would face the same problem again in 100 years because Earth’s rotation will continue to slow.

One solution might be to keep a scientific and technological second as defined now, and a civil second that would be a little longer and would be lengthened every 50 years. This would eliminate the need for leap seconds.

Les Essarts-le-Roi, France

It’s realistic to be alarmed

From John Hunwick

There are many areas of uncertainty associated with climate change, but for scientists to continually err on the side of being conservative does not serve their wider audience at all. In fact, it inhibits urgent action.

It is clear from your piece on superstorms (1 August, p 9) that one scientist, James Hansen, has not lost his sense of realism and has consistently made predictions that prove to be far more accurate than those of his colleagues.

Nearly all other “official” projections of climate scientists

have turned out to be too conservative. If the talks in Paris at the end of the year are to make progress toward correcting the present situation, then real scientists being realistic must be heard loud and clear.

Port Lincoln, South Australia

From Tony Maskell

Typhoons are being made worse by global warming, but I believe we can try to reduce their power and/or frequency.

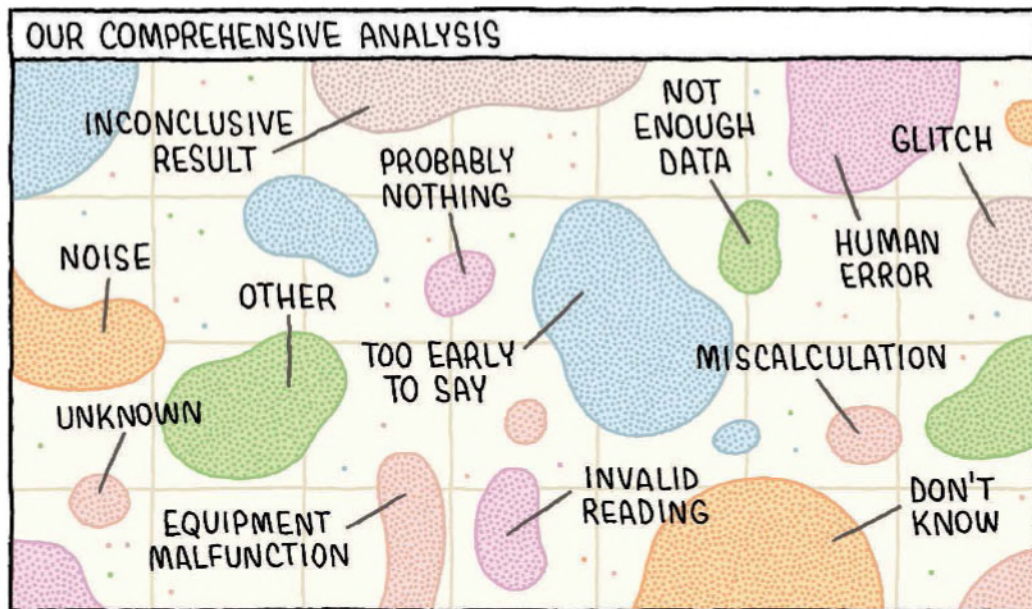
Hurricanes, typhoons and cyclones get their energy from a relatively thin layer of warm water at the surface of tropical seas. This layer also threatens phytoplankton with overheating.

Satellite heat sensors show these storms leave a line of cooler water in their wake – which we have the technology to emulate by bringing cold water from deeper down during the typhoon season to deny these storms the energy they need to worsen.

One method would be to bubble compressed air into the sea at a depth of, say, 100 metres.

Plymouth, UK

TOM GAULD



Scouting for true north

From Martin Savage

I was surprised that someone would go to the trouble of using GPS and a digital camera to find true north from the position of the sun (8 August, p 13). Anyone who was ever a boy scout knows how to do this with an old-fashioned wristwatch.

Jomtien, Thailand

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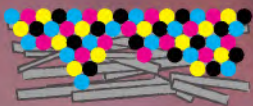
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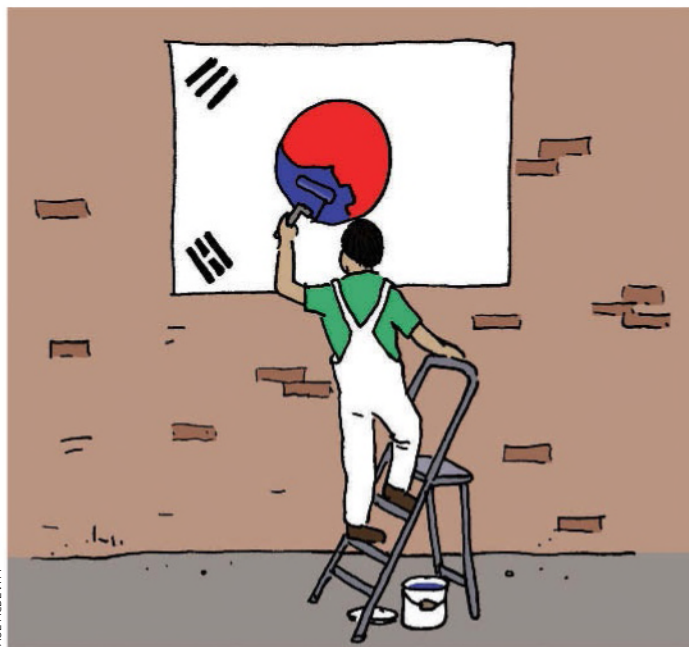
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PAUL McDEVITT

A ROSE by any other name would smell as sweet – except to officials in South Korea, who have marked 70 years of independence by renaming thousands of native flora species that referenced the country's former colonial ruler.

Hereafter, the Japanese red pine will be known as the Korean red pine, and so forth. Unfortunately, the International Code of Nomenclature for Algae, Fungi and Plants is less forgiving: it dictates that scientific names cannot be changed, even if there is a whiff of cultural imperialism about them.

But Latin names can be anti-imperialist, too. A new species of crayfish has been dubbed *Cherax snowden* after the intelligence analyst who leaked details of mass surveillance activities by the US and other governments, and who has remained in political exile ever since.

Of the unusual choice in name, researcher Chris Lukhaup wrote: "the new species is named after the American freedom fighter Edward

Joseph Snowden. He is honored due to his extraordinary achievements in defense of justice, and freedom."

Sure, it's no Presidential Medal of Freedom, but Snowden is unlikely to be collecting one of those any time soon. Feedback suspects that there is no shortage of pointedly political nomenclature shoehorned into Latin binomials around the world. We invite your best examples.

BREVITY is the soul of wit, and perhaps of scientific paper citations as well. That's the conclusion of a study published in *Royal Society Open Science*, which analysed 140,000 papers for impact and titular terseness.

The authors speculate that shorter titles may give the impression that the paper's contents are easier to understand, thus attracting readers.

This important work builds on an earlier investigation published in the *Journal of Information Science* in 2007, which examined

1009 titles to learn whether tickling readers' funny bones could boost the success of a paper.

"While the pleasantness rating was weakly associated with the number of citations," the authors state, "articles with highly amusing titles (2 standard deviations above average) received fewer citations." Let nobody say that science isn't a serious business.

Feedback suspects there is a confounding factor at play: namely, what is funny? Titles rated as highly humorous by the panel of judges include "Beware the half-tailed test" and "The unicorn, the normal curve, and other improbable creatures". Readers, we're sure you can offer better examples.

MORE terms of engagement: one of our US correspondents says that from his side of the Atlantic, it's easy to see another explanation for the discrepancy between the number of sexual partners reported by men and women (22 August). As we learned during then-president Bill Clinton's impeachment, it depends on how you define sexual relations.

Clinton's lawyers set out a definition that rested on who touches what parts of whom. This reading would allow Monica Lewinsky to have engaged in sexual relations with Clinton, but he wouldn't have engaged in sexual relations with her. Perhaps those surveyed carried out similar semantic gymnastics.

DESPITE sounding like a B-movie thriller, *The Sky at Night* is in fact a genteel, astronomy-themed staple of British television. However, Helen Austin writes to say that proceedings threatened to take a dark turn during an episode on the New Horizons probe bound for Pluto, the dwarf planet discovered by Clyde Tombaugh in 1930.

"Sadly, Clyde passed away before New Horizons launched," said one presenter. This is probably a good thing, writes Helen, "as only minutes earlier

the programme had informed viewers that Clyde's ashes were interred in the spacecraft".

SOMETHING odd is stewing in Cumbria, UK, where Anthony Baker reports the purchase of a stockpot from his local Tesco. "I was more than pleased to discover it is 'suitable for use with foodstuffs', according to a label on the packaging," says Anthony, "though it makes me wonder what sort of soup I'd be making if it wasn't."

PEDLARS of pseudoscience often take scientific names in vain to persuade consumers there is a solid basis for expensive guff, writes Matt Ashmore, "but is there a specific term for when ordinary things are elevated into expensive guff by using accurate,



if unfamiliar, scientific terms?"

By way of an example, he points to "micellar water", a beauty product currently in vogue that promises to gently remove make-up and dirt using tiny balls of cleaning chemicals (micelles) suspended in water.

"I've been using micellar water to wash my dishes, and indeed my unmentionables, for as long as I can remember," says Matt, "as it seems that it is just a way of selling some kind of weak soap solution for £50 per litre."

You can send stories to Feedback by email at feedback@newscientist.com. Please include your home address. This week's and past Feedbacks can be seen on our website.

The Magnetic Swarovski Crystal Tennis Bracelets spotted by Chris Mitchell may prove awkward to wear: he is informed that "all the magnets face the North Pole for better results"

Dung addicts

We muck out our horse paddock twice a day. In the late summer and autumn, there are usually one to three dark-blue iridescent beetles sitting in burrows beneath the horse droppings. How do they get there in such a short time, which is perhaps 12 hours at most? Do the beetles come through the soil (which is often very hard and dry in the summer) or do they travel over the ground?

■ The beetles burrowing in the horse droppings have almost certainly flown there, attracted by the smell. They are likely to be dung beetles, of the family Scarabaeidae (scarab beetles). Dung beetles are loosely divided into rollers, burrowers and dwellers. Rollers will roll a ball of dung away and bury it for food or egg-laying. Burrowers dig down into the dung, feeding and breeding inside it. Dwellers live on top of the dung. Your beetles seem to be burrowers.

Most dung beetles have an exquisitely sensitive sense of smell and are powerful flyers. To avoid competition, and lessen the risk of the dung drying out and becoming impossible to mine, the beetles arrive very quickly.

I worked for 20 years in Zambia and frequently had to take trips into the bush. On one occasion I was driving alone on a remote road and pulled over to relieve myself. As I crouched, there was a loud buzzing and, when I stood up, I saw a dung beetle had arrived and was already hard at work,

expertly forming a portion into a ball. Having done so, the beetle hurried away with it.

As I watched, grimly fascinated, another arrived on the wing, and then another, and another. I was so astonished that I didn't think to count how many there were, but within 30 minutes there wasn't a trace of my faeces left. Still more dung beetles flew in, presumably attracted by the residual smell, and wandered around forlornly. It was one of my more memorable wildlife experiences.

*Alistair Scott
Gland, Switzerland*

■ Some years ago I released five species of dung beetle on to our farm in southern New South Wales. These species originated in South Africa, and after years of testing were allowed into Australia, along with other species.

The reason that the beetles arrive on the dung so quickly is that they are strong flyers, some with quite a loud buzz.

"Dung beetle eggs are laid in cowpats, and the larvae hatch in about three days and dig tunnels"

Eggs are laid in cowpats, and the larvae hatch in about three days and dig tunnels, pulling the dung down. This kills any fly larvae that are present, which take five days to hatch.

A fly can lay about 3,000 eggs on one cowpat, so the improvement of my farm pasture and the

reduction of fly numbers have been striking.

*David Hamilton
Sydney, Australia*

Ears tuned

Hearing aids pick up airborne acoustic signals, and can be switched to receive signals from an induction loop. Why haven't they been designed to receive TV and radio signals directly?

■ The main reason hearing aids don't pick up TV or radio directly is size. A TV aerial needs to be big to capture the signal, and it won't fit into a hearing aid. Even with a strong signal, hearing aids use very small zinc-oxide batteries which have limited capacity, restricting their ability to perform the necessary tasks.

However, the industry is working to solve these problems. Hearing-aid and technology companies are working with the Bluetooth standards group to transmit and receive audio over the low-energy version of Bluetooth. Your hearing aid won't receive TV or radio signals directly; rather, the audio will be wirelessly transmitted from your TV, tablet or phone to your hearing aid.

The technology is also being designed to replace the current telecoil inductive loops in public places, providing higher quality along with the ability to listen to sound in stereo.

*Nick Hunn
London, UK*

This week's questions

DECKCHAIR PORT

I notice that Heathrow Airport often tops the list of highest daily temperatures in summer in the UK. Why is this?

*Katriona Sewell
London, UK*

CHROMATIC QUANDARY

If subatomic particles could be seen with the naked eye, what colours would they be?

*Michael Green
Seaview, Isle of Wight, UK*

FISHY HELL

I don't like eating fish and I find their odour disagreeable. My wife says it's all in my head, but I think that many people have my aversion. Is there a genetic or evolutionary component to it, is it based on an unpleasant childhood experience, or do I have to concede to my wife's theory?

*Al Morin
London, UK*

NUTTY QUESTION

Why is the scrotum so wrinkly?

Neil Smith

By email, no address supplied

UNCOMMON ANCESTOR

Like other white Europeans I carry about 2.5 per cent Neanderthal genes, more than indigenous Africans. If we all walked out of Africa about 100,000 years ago, what is the explanation for this?

*A.M. Bryant
La Reortiere, Le Busseau, France*

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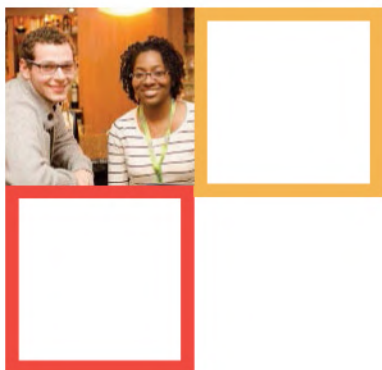
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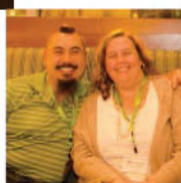
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